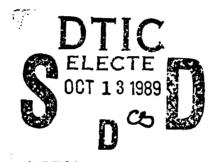Technical Report 858

Human Factors Research in Aircrew Performance and Training: 1988 Annual Summary Report

D. Michael McAnulty and Theodore B. Aldrich
Editors, Anacapa Sciences, Inc.

August 1989

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for the Behavioral and Social Sciences

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U.S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction
of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

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Commanding

Research accomplished under contract
for the Department of the Army

Anacapa Sciences, Inc.

Technical review by

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This report presents summaries of the research projects performed by Anacapa Sciences, Inc., for the ARI Aviation R&D Activity (ARIARDA) at Fort Rucker, Alabama. From 9 October 1987 to 8 October 1988, Anacapa personnel worked on 25 research projects and took part in 6 technical advisory services that address emerging aviation weapon systems design, manpower and personnel programs, and aviator training research. The summary for each project and technical advisory service contains (a) a background section that describes the rationale for the project and specifies the research objectives, (b) a research approach section that describes the tasks and activities required to meet the project objectives, (c) a results section that describes the research findings or, in the case of developmental activities, the research products, and (d) a project status section that describes the work completed and projections for future research, if any. (Kennard?)

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Technical Report 858

Human Factors Research in Aircrew Performance and Training: 1988 Annual Summary Report

D. Michael McAnulty and Theodore B. Aldrich
Editors, Anacapa Sciences, Inc.

ARI Aviation R&D Activity
Charles A. Gainer, Chief

Training Research Laboratory
Jack H. Hiller, Director

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, is contributing to the effectiveness of Army aviation by conducting a comprehensive human factors research program in support of aircrew performance and training. The ARIARDA research program encompasses the full range of Army aviation, with projects in support of (a) emerging Army aviation weapon systems, (b) aviator selection, (c) manpower and personnel integration (MANPRINT), and (d) aviator training programs. The MANPRINT and emerging aviation systems work was performed as part of the Systems Research Laboratory's Human Factors Training Operational Effectiveness Project A793. The aviator training work was executed as part of the Training Simulation Project A795 in the Training Research Laboratory. Finally, the aviator selection research was performed as part of Manpower and Personnel Project A792, within the Manpower and Personnel Research Laboratory.

The research efforts summarized in this report respond to several Memorandums of Agreement (MOAs) between the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) and Aviation Systems Command (AVSCOM), Training and Doctrine Command (TRADOC), the U.S. Army Aviation Center (USAANVC), and Combined Arms Test Activity (CATA). Some of the work was in direct response to letters from agencies in the sponsoring organization. Each project summary lists the agency, the product, and the outcome.

This report summarizes research performed and products developed in all three of the above areas between 9 October 1987 and 8 October 1988. Twenty-five projects are described under 16 research area summaries. Ten projects describe research in support of emerging systems, 5 present research in support of manpower and personnel programs, and 10 report accomplishments in support of aviator training programs. In addition, 6 technical advisory services are described.

This summary report is intended to meet two important objectives. First, it provides U.S. Army weapon system managers, manpower and personnel planners, and training system developers and managers with a summary of research progress and accomplishments

in their areas of responsibility. Second, it provides summary
information to behavioral scientists who may be working on simi-
lar applied research issues, either in the Department of Defense
or in other governmental, industrial, or university
organizations.

EDGAR M. JOHNSON
Technical Director

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1988
ANNUAL SUMMARY REPORT

EXECUTIVE SUMMARY

Requirement:

Anacapa Sciences, Inc., has provided research support to the
U.S. Army Research Institute Aviation Research and Development
Activity (ARIARDA) at Fort Rucker, Alabama, since 1981. The
ARIARDA program supports the full range of Army aviation research
requirements with projects that address emerging aviation weapon
systems, aviation manpower and personnel programs, and aviator
training programs. This report describes the 25 research proj-
ects and 6 technical advisory services conducted by Anacapa
Sciences, Inc., researchers between October 1987 and October 1988
in support of the ARIARDA program. The specific requirements
that led to each research project are discussed in the individual
summaries.

Procedure:

There are substantial differences in the methods used in the
individual projects and in the technical advisory services. In
some cases, the research approach was a scientific experiment in
which selected variables were controlled, manipulated, and meas-
ured. In other cases, the research approach was a set of anal-
ytical or product development tasks. The specific research
methods used in each project and technical advisory service are
described in moderate detail in the individual summaries.

Findings:

The research projects were conducted in all three domains of
the ARIARDA research program. The 25 projects are described in
16 research summaries. Ten of the projects address the emerging
aviation weapon systems program. Eight of these projects address
the prediction of operator workload in varying configurations of
the LHX, AH-64, UH-60, MH-60K, and MH-47E helicopters. The other
two projects are concerned with flight symbology and integration
of maintenance considerations during the early design phases of
new aircraft.

Five of the projects are in the manpower and personnel research program: the development of a new aviator selection test, the development of a peer assessment method, an evaluation of the First Army Reserve aviation management method, an evaluation of Reserve Component training requirements, and a survey of aviation ammunition and gunnery training practices and requirements. The remaining ten projects are part of the aviator training research program. Five of the projects are concerned with the evaluation of flight simulator training in operational Army aviation units. The other five projects are concerned with upgrading the basic map interpretation and terrain analysis course to videodisc, developing an AH-64 symbology training program, surveying the research on computer-based instruction, and conducting two evaluations of the effectiveness of aviation part-task trainers.

The six technical advisory services were concerned with determining the LHX simulation requirements, participating in all the Special Operations Aircraft Program in-progress reviews and crew station working group meetings, developing an AH-64 automated target handover system, developing a multitrack classification battery, evaluating the relationship between handedness and flight training performance, and developing software for a flightline research system.

Utilization of Findings:

The results and recommendations of many of the projects and technical advisory services will aid in the design of new aviation systems, in the selection and management of aviation personnel, and in aviation training at the Aviation Center at Fort Rucker, and in world-wide Army aviation units. This report provides Army weapon systems managers, manpower and personnel planners, training system developers and managers, and other researchers working in related fields with a summary of the research activities in their respective areas of interest.

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1988
ANNUAL SUMMARY REPORT

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AA   Active Army
AA   Assembly Area
AAA   Army Audit Agency
AQC   Aircraft Qualification Course
ARIARDA   Army Research Institute Aviation Research and
                Development Activity
ARMS   Aviation Resource Management Survey
ARNG   Army National Guard
ARTI   Advanced Rotorcraft Technology Integration
ATB   Apache Training Brigade
ATC   Army Training Command
ATHS   Airborne Target Handover System
ATHS/AI   ATHS Avionics Integration
AVG   Final Academic Averages
AVNOAC   Aviation Officer Advanced Course
AVRADA   Army Avionics Research and Development Activity
AVSCOM   Aviation Systems Command
BCS   Basic Combat Skills
CATA   Combined Arms Test Activity
CBAC   **Cavalry Brigade--Air Combat**
CMS   Combat Mission Simulator
CO   Commissioned Officer
CONUSA   Continental United States Army
CPG   Copilot/Gunner
CRT   Cathode Ray Tube
CSRDF   Crew Station Research and Development Facility
CSWG   Crew Station Working Group
CWEPT   Cockpit Weapons Emergency Procedures Trainer
DA   Department of the Army
DCST   Deputy Chief of Staff for Training
DEM/VAL   Demonstration/Validation
DGFS   Directorate of Gunnery and Flight Systems
DOTD   Directorate of Training and Doctrine
ECP   Engineering Change Proposal
EEA   Essential Elements of Analysis
EGA   Enhanced Graphics Adapter
ETM   Emergency Touchdown Maneuver
FAR   Faculty Advisor Rating
FARP   Forward Area Arming and Refueling Point
FAST   Flight Aptitude Selection Test
FLIR   Forward-Looking Infrared
FM   Field Manual
FORSCOM   Forces Command
FWS   Flight and Weapons Simulator
FY   Fiscal Year
HMD   Helmet-Mounted Display
IAS   Integrated Avionics System
IERW   Initial Entry Rotary Wing

IP	Instructor Pilot
IPR	In-Progress Review
LHX	Light Helicopter Family
LOS	Line-of-Sight
LZ	Landing Zone
MANPRINT	Manpower and Personnel Integration
MFD	Multifunction Display
MITAC	Map Interpretation and Terrain Analysis Course
MOA	Memorandum of Agreement
MOE	Measure of Effectiveness
NFAST	New Flight Aptitude Selection Test
NG	National Guard
NOE	Nap-of-the-Earth
PC	Peer Comparison
PFTEA	Post-Fielding Training Effectiveness Analysis
PM	Program Manager
PNVS	Pilot Night Vision System
PZ	Pick-Up Zone
RC	Reserve Component
RFAST	Revised Flight Aptitude Selection Test
SAM	School of Aerospace Medicine
SET	Simulation Evaluation Team
SFTS	Synthetic Flight Training System
SME	Subject Matter Expert
SOA	Special Operations Aircraft
SOF	Special Operations Forces
STRAC	Standards in Training Commission
TADS	Target Acquisition and Detection System
TAWL	Task Analysis/Workload
TRADOC	Training and Doctrine Command
TSTT	Target Acquisition and Detection System Selected Task Trainer
USAAVNC	United States Army Aviation Center
USAR	United States Army Reserve
USAREUR	United States Army, Europe
VAX	MicroVax II Microcomputer
VRS	Video Recorder Subsystem
WOC	Warrant Officer Candidate

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING:
1988 ANNUAL SUMMARY REPORT

INTRODUCTION

Anacapa Sciences, Inc., has provided collocated research
support to the U.S. Army Research Institute Aviation Research
and Development Activity (ARIARDA) at Fort Rucker, Alabama,
under a series of contracts that began 1 September 1981. The
current contract (No. MDA903-87-C-0523) requires the submis-
sion of an Annual Summary Report of research project activi-
ties. Project activities during the first contract year were
reported in Aldrich and McAnulty (1987). This report
describes the Anacapa research project activities and achieve-
ments during the period from 9 October 1987 to 8 October 1988.
Throughout the report, this period is referred to as the
current contract year.

During the 1988 in-progress review, some of the Anacapa
project activities were reorganized to (a) facilitate project
accounting, (b) distribute resources in accordance with
current and projected funding, and (c) increase productivity.
Two major changes were implemented and are reflected in the
organization of this report. First, some of the major long-
term research projects were designated as research areas and
divided into discrete projects that will each conclude with a
deliverable product. As a result, some of the research
summaries in this report describe more than one project.
**Second, a new category of activities called technical advisory
services was established to provide research findings and expert
assistance to Army programs and projects that are not directly
assigned to Anacapa Sciences.**

The first section of this report contains summary
descriptions of 25 projects that Anacapa personnel have
worked on during the current contract year. Six technical
advisory services provided during the current contract year
are summarized in the second section of this report. Most of
the project and technical advisory services summaries follow
the same general format. Each summary begins with a back-
ground section that presents information needed to understand
the requiremen+ for the project. The background may include
a brief review of the relevant research literature or
describe the critical events that led to the initiation of
the project or technical advisory service. Where appro-
priate, the relationship between specific projects in a
research area or between an Anacapa research project and a
technical advisory service is discussed.

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When the need for the research cannot be clearly inferred from the background information, a statement of need or definition of the research problem is presented. This is followed by a concise statement of the project or research area objectives. Next, the research approach section presents a description of the activities that were planned to accomplish the research objectives. For some projects, the research approach is a scientific experiment in which selected variables are controlled, manipulated, and measured. For other projects, the research approach is a set of analytical or product development tasks.

In the project summaries, the research approach is usually followed by one or more sections that present the research findings or, in the case of product development efforts, a summary description of the research products. In the technical advisory service summaries, the research approach is usually followed by a description of the services provided by Anacapa personnel. The final section of each summary, entitled "Project Status," describes the work accomplished during the contract year and the work projected, if any. This section also identifies delivered products and reports and, where possible, presents the current project milestones.

Anacapa personnel also provided temporary research, technical, administrative, and logistical support on other projects that are the primary responsibility of ARIARDA personnel and are, consequently, not summarized in this report. It is also important to note that the projects summarized in this report represent only a portion of ARIARDA's research program. Numerous other projects are being conducted either in-house by ARIARDA personnel or under other contracts.

The project summaries are presented in three content categories that reflect the research domains at ARIARDA. This organization is intended to assist the reader in locating a specific project summary within a research domain or to find summaries that are closely related in terms of content.

The first six summaries describe ten projects in emerging aviation systems design. The next five summaries present projects in manpower and personnel research. The last five summaries describe ten aviator training research projects. The number of projects assigned to the three categories is not necessarily in proportion to the emphasis placed on each research domain.

The project summaries are followed by descriptions of the six technical advisory services. Technical advisory services were provided to support (a) aviation system research and development programs being managed by Aviation Systems Command managers and engineers, and (b) aviation projects being conducted by ARIARDA scientists. The first three summaries describe technical advisory services provided in support of emerging aviation systems design. The next two summaries describe technical advisory services provided in support of manpower and personnel research. The sixth summary describes a technical advisory service provided in support of an ARIARDA training research project.

Although each summary identifies the project director(s) or technical advisor(s), the Anacapa approach to research employs a team concept. This approach provides the optimum utilization of each scientific staff member's skills and ensures coordination among closely related projects. The scientific staff members are supported by an exceptionally efficient administrative and technical staff. All of the research effort is closely coordinated with ARIARDA personnel.

Reference

Aldrich, T. B., & McAnulty, D. M. (1987). Human factors research in aircrew performance and training: Annual summary report (Technical Report ASI690-304-87). Fort Rucker, AL: Anacapa Sciences, Inc.

VALIDATION OF THE LHX WORKLOAD PREDICTION MODEL
Mr. Theodore B. Aldrich, Project Director

Background

Models that predict operator workload can be useful tools for human factors engineers who are addressing human capabilities and limitations during the design of advanced technology weapon systems. Accordingly, Anacapa Sciences researchers, under contract to the U.S. Army Research Institute Aviation Research and Development Activity, developed a workload prediction methodology and produced one- and two-crewmember models for predicting aviator workload in advance of aircraft system design. The workload prediction methodology operationally defines workload in terms of attentional demand and predicts workload associated with task-level performance. The Anacapa researchers applied the workload prediction models during the conceptual design phase of a proposed multipurpose, lightweight helicopter designated the LHX (Aldrich, Szabo, & Craddock, 1986).

Need

Neither the workload predictors used to develop the models nor the workload predictions yielded by the models have been validated. Workload model predictors that require validation include the:

- workload ratings assigned to each task,
- total workload estimates for concurrent tasks,
- estimated time required to perform each task,
- temporal relationships among tasks, and
- sequential relationships among tasks.

Specific predictions yielded by the models that require validation include the four indexes of excessive workload (Aldrich, Craddock, & McCracken, 1984) listed below:

- component overloads,
- overload conditions,
- overload density, and
- subsystem overloads.

Project Objectives

This project is divided into three phases. The objectives of Phase 1 are to evaluate the reliability of (a) the scales used to rate the workload components of each operator task identified during the LHX workload analyses and (b) the

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workload predictors used in developing the LHX workload
prediction model. The objective of Phase 2 is to obtain
validation data through part-mission and full-mission flight
simulation research. The objective of Phase 3 is to refine
the workload prediction model on the basis of validation
research results.

Methodology

A research plan designed to meet the above objectives
was produced early in the first contract year (Aldrich &
Szabo, 1986). The research plan provides detailed descrip-
tions of 18 tasks required to accomplish the three phases of
the validation research. A summary of the research method-
ology for each of the three phases is described below.

Phase 1

In Phase 1, two surveys will be administered to human
factors scientists who are familiar with workload research.
In the first survey, all possible pairs of the verbal anchors
from each of the workload component rating scales are pre-
sented to the workload subject matter experts (SMEs). The
SMEs will select the anchor in each pair that requires the
greatest attentional demand. The results of this survey will
be used to assess the interrater reliability of the scale
anchors. The data will also be used to produce equal
interval scales (e.g., Engen, 1971) to replace the ordinal
scales that were used in the original workload analysis.

The second survey asks the same SMEs to use the workload
component scales to rate the short descriptors of visual,
auditory, cognitive, and psychomotor components of workload
for each task in the model. Correlational techniques will be
used to evaluate the interrater reliability of the workload
ratings.

Phase 2

In Phase 2, part-mission and full-mission simulation
experiments will be conducted to validate the workload esti-
mates. For the part-mission simulation, mini-scenarios will
be generated by selecting concurrent and sequential tasks
from the mission/task analysis. For the full-mission simu-
lation, a composite mission scenario will be developed by
selecting segments from the mission/task analysis.

The part-mission simulation experiments will be conducted using a repeated measures experimental design in which each subject will fly the mini-scenarios multiple times. The results will be analyzed by correlating the workload predictors and the measures of the operators' performance on the concurrent and sequential tasks. The correlation coefficients will indicate how accurately the workload predictors forecast excessive workload at the task level. To assess the validity of the time estimates used in the model, the time required to perform the various tasks in the mini-scenarios will be compared with the times estimated during the task analysis. The procedural relationships among the tasks will be evaluated by noting the subjects' ability to progress through the mini-scenarios following the sequence of tasks specified by the model.

During the full-mission simulation experiments, each trial will start at the beginning of a composite scenario and continue without interruption to the end. All the part-mission simulation data analyses will be conducted on the full-mission simulation data. In addition, an analysis will be performed to assess the effects of inserting secondary tasks into the composite mission scenario.

The final task in Phase 2 will be to compare the results from the part-mission simulation research with results from the full-mission simulation research. The findings from this comparison will be used to determine if excessive workload results from the cumulative effects of high workload over the longer times in the composite mission scenario.

Phase 3

In Phase 3, refinements will be made to the workload prediction model on the basis of the results from the first two phases. First, the workload component rating scales will be converted from ordinal to interval scales. Second, refinements will be made to the workload model algorithms to reflect the empirical results of the part-mission and full-mission simulation experiments.

Results

Phase 1

The first survey has been conducted. A survey instrument was developed that presented all possible pairs of the verbal anchors from each of the four workload component

rating scales. The instrument was mailed to 71 SMEs who selected the verbal anchor in each pair judged to require the greatest attentional demand. The data from 38 completed survey instruments were used to develop each rater's rank order judgment of the verbal anchors. Kendall's Coefficient of Concordance (Siegal, 1956) was used to assess the degree of agreement among the SMEs. The Coefficients of Concordance for the four scales are as follow:

- Visual - .39,
- Auditory - .46,
- Cognitive - .69, and
- Psychomotor - .47.

All of the Coefficients of Concordance are significant at the .001 level and indicate a moderate degree of consensus among the SMEs.

Phase 2

In October 1987, a new Crew Station Research and Development Facility (CSRDF) located at the Army's Aeroflightdynamics Laboratory, NASA Ames, Moffett Field, California, was selected as the most appropriate site for conducting the validation research. CSRDF researchers originally planned to support the LHX validation research with part-mission simulation research scheduled during October 1988, January 1989, and April 1989 and full-mission simulation research scheduled from July through September of 1989.

In April 1988, CSRDF planners postponed the simulation research from October 1988 until October 1989 because of delays in acquiring a new Compuscene IV visual system and because of changes in research priorities. CSRDF simulation planners also stated that the initial LHX validation research should be full-mission simulation with two crewmembers. This differs from the project research plan that begins with the part-mission, one-crewmember simulation.

Phase 3

The data from the pair comparison survey were used to construct interval values for the workload component scales. The workload prediction model was refined by replacing the original ordinal values for each task with the interval values. The one-crewmember workload model was exercised with the new interval scale values to produce estimates of workload for each of the 29 mission segments in the model.

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Table 1 presents a comparison of the workload predicted by the interval scale values and the ordinal scale values. The results presented are total values for all 29 segments in the model. Although there are some differences, interval scale values closely correspond to the results produced by the ordinal scale values.

Table 1

Workload Predicted by the Ordinal and Interval Scale values

| | Overload Conditions | Component Overloads | | | Overload Density |
		Visual	Cognitive	Psychomotor	
Ordinal Values	263	81	52	203	.206
Interval Values	292	94	92	224	.202

Project Status

Phase 1

The final step in Phase 1 is to design and administer a second survey instrument. The instrument will request that SMEs rate verbal descriptors of LHX tasks using the workload component scales. Data from the survey will be used to assess the interrater reliability of the scales.

Phase 2

CSRDF plans have forced a delay in the work required to accomplish Phase 2. Anacapa still plans to use flight simulation to validate the LHX workload prediction model, but the plans depend upon access to a high-fidelity, high-technology flight simulator.

Phase 3

Further comparisons will be made between the interval and ordinal scale values with the two-crewmember model and

with various automation options. Additional refinements may be identified when the model is exercised to produce workload predictions using the new scale values.

Additional refinements will be made to the workload prediction model when the flight simulation research is conducted and analyzed. Refinements that may be introduced include changes to the workload estimates, time estimates, and decision rules. New workload predictions will be produced following each improvement in the model.

References

Aldrich, T. B., Craddock, W., & McCracken, J. H. (1984). A computer analysis to predict crew workload during LHX scout-attack missions (Technical Report ASI479-054-84). Fort Rucker, AL: Anacapa Sciences Inc.

Aldrich, T. B., & Szabo, S. M. (1986). Validation of the LHX one-crewmember workload prediction model (Draft Technical Memorandum ASI678-202-86[B]). Fort Rucker, AL: Anacapa Sciences Inc.

Aldrich, T. B., Szabo, S. M., & Craddock, W. (1986). A computer analysis of LHX automation options and their effect on predicted crew workload (Draft Technical Report ASI479-063-85[B]). Fort Rucker AL: Anacapa Sciences Inc.

Engen, T. (1971). Psychophysics II: Scaling methods. In J. W. Kling and L. A. Riggs (Eds.), Experimental psychology (3rd ed.), pp. 51-54. New York: Holt, Rinehart, and Winston.

Siegal, S. (1956). Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill.

DEVELOPMENT OF A TASK ANALYSIS/WORKLOAD (TAWL) SOFTWARE SYSTEM

Ms. Cassandra Hocutt, Project Director

Background

Anacapa Sciences researchers, under contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, have developed a methodology for predicting operator workload during the conceptual phase of new weapon system development. The methodology was first applied to the Army's Light Helicopter Family (LHX) aircraft (McCracken & Aldrich 1984; Aldrich, Craddock, & McCracken, 1984; Aldrich, Szabo, & Craddock, 1986).

Subsequently, Anacapa personnel refined the mission/task/workload analysis methodology and produced operator workload prediction models for the AH-64A (Szabo & Bierbaum, 1986), the UH-60 (Bierbaum, Szabo, & Aldrich, 1987), and the CH-47 aircraft. Each of the original workload prediction models was programmed in FORTRAN 77 on a Perkin-Elmer 3210. Currently, Anacapa researchers are developing workload prediction models for the MH-60K and the MH-47E aircraft. The Anacapa project director is developing a software system, called the Task Analysis/Workload (TAWL), that is capable of exercising any of the models developed with the refined methodology.

Need

Programs for the LHX, AH-64A, and UH-60 workload prediction models incorporate the model decision rules into the actual program code. Time-consuming recompilations of the programs are required to incorporate even minor changes in the models. A software system is required that reduces the development time for implementing changes to existing models or creating new models.

Project Objectives

The primary objective of this project is to develop a software system that (a) can incorporate model changes without rewriting and recompiling the software, and (b) is powerful and flexible enough to exercise any of the workload prediction models developed with the refined mission/task/workload analysis methodology. In addition, the software system should be:

- easy to use,
- portable, and
- easy to modify in accordance with changing require-
  ments created by the development of a new workload
  prediction model.

Approach/Methodology

The TAWL software system uses data files to store all
model information peculiar to a specific aircraft. This
design approach enables the programmer:

- to change an existing model's execution by changing
  its data files, thereby eliminating the need to
  rewrite and recompile the program to incorporate the
  changes; and
- to implement new computer models developed with the
  refined methodology merely by creating a new set of
  data files.

Although the technique of using data files to store all
model information resolved the problems described above, the
data entry of model information using an editor is time
consuming and subject to errors. A data base management
system with specialized routines was designed for entering
and updating all of the data used in the workload prediction
models. Each specialized routine features customized error
checks to help ensure the validity of the data files. The
most critical data files are protected by automatic backup
procedures.

A simple and consistent user-interface was developed to
produce a system that is easy to use. The software system
was developed for use on an IBM AT compatible computer to
meet the objective of portability. Turbo Pascal 4.0 was
selected as the development language to meet the objective of
easy modification. Turbo Pascal 4.0 has the following
features.

- The control and data structures can support the design
  complexity required to exercise the workload
  prediction models.

- The control and data structures enable the programmer
  to produce code that is clean, clear, and easy to
  modify.

- The excellent development environment includes special
  debugging features and a built-in editor designed for
  program-style documents.

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- The rigid syntax enables the compiler to identify errors that require time-consuming debugging in other languages.

Project Status

Work Completed

The first version of the TAWL software system has been released and is currently in use. It was used to exercise the CH-47 model and is being used to build a data base for the revision of the AH-64A model. A data base for the UH-60 model was created and validated using TAWL's current version. Finally, work has begun on creating TAWL data files for the MH-47E and the MH-60K helicopters.

A copy of the software system, TAWL's UH-60 data files, and a draft user's guide have been submitted for testing and review by personnel at the ARI AVSCOM Element office, St. Louis, Missouri.

Work Projected

Work will continue on the implementation of the TAWL system for the AH-64A, MH-47E, and MH-60K models. Other models or changes to existing models will be implemented as required. A limited directory utility with a graphic interface is scheduled for the TAWL software system as a design improvement. The utility will be developed as a separate program and will be incorporated into the software system after the directory and file routines have been tested. The directory utility will add the following improvements to the software system:

- the ability to build and work with a data base in any directory (TAWL's current version is limited to the root directory or a first-level directory);
- the ability to add, delete, and rename directories;
- the ability to rename, copy, and move files; and
- an improved interface for all file and directory routines.

Other improvements will be scheduled as needs arise. A user's guide for the TAWL software system also will be produced.

References

Aldrich, T. B., Craddock, W., & McCracken, J. H. (1984, October). <u>A computer analysis to predict crew workload during LHX scout-attack missions</u> (Technical Report ASI479-054-84[B], Vols. I, II, III). Fort Rucker, AL: Anacapa Sciences Inc.

Aldrich, T. B., Szabo, S. M., & Craddock, W. (1986). <u>A computer analysis of LHX automation options and their effect on predicted crew workload</u> (Draft Technical Report ASI479-063-85[B]). Fort Rucker AL: Anacapa Sciences Inc.

Bierbaum C. R., Szabo, S. M., & Aldrich, T. B. (1987). <u>A comprehensive task analysis of the UH-60 mission with crew workload estimates and preliminary decision rules for developing a UH-60 workload prediction model</u> (Draft Technical Report ASI690-302-87[B], Vol. I, II, III, IV). Fort Rucker, AL: Anacapa Sciences Inc.

McCracken, J. H., & Aldrich, T. B. (1984, June). <u>Analyses of selected LHX mission functions: Implications for operator workload and system automation goals</u> (Technical Note ASI479-024-84[B]). Fort Rucker, AL: Anacapa Sciences Inc.

Szabo, S. M., & Bierbaum, C. R. (1986, October). <u>A comprehensive task analysis of the AH-64 mission with crew workload estimates and preliminary decision rules for developing an AH-64 workload prediction model</u> (Technical Report ASI678-204-86, Vols. I, II, III, and IV). Fort Rucker, AL: Anacapa Sciences, Inc.

UH/MH-60 AND CH/MH-47 TASK/WORKLOAD ANALYSES

Mr. Carl R. Bierbaum, Project Director

Background

The U.S. Army presently utilizes CH-47D and UH-60A aircraft to support Special Operations Forces (SOF). Although the SOF aircraft have special systems to assist pilots in performing the special operations missions, the Special Operations Aircraft (SOA) Program Manager's (PM) Office at the Army's Aviation Systems Command has been tasked to develop an MH-60K and an MH-47E aircraft for the SOF. The SOA will consist of existing CH-47D and UH-60A airframes with new integrated cockpits. Specifically, four multifunction display (MFD) units will replace the existing instrument and gauge configurations in both the CH-47D and UH-60A aircraft.

Anacapa Sciences researchers, under contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), have developed a methodology for predicting operator workload during system design. Initially, the workload prediction methodology was developed and applied to the design of the Army's light helicopter family (LHX) aircraft (Aldrich, Szabo, & Craddock, 1986). Later, the LHX workload prediction methodology was refined and used to predict workload encountered by operators of the following helicopter systems:

- the AH-64A Apache (Szabo & Bierbaum, 1986), and
- the UH-60A Black Hawk (Bierbaum, Szabo, & Aldrich, 1987).

The high technology modifications proposed for the SOA cockpits may increase workload by placing additional mental and visual demands on crewmembers as they attempt to interpret the many MFD options. Therefore, the SOA PM Office requested that ARIARDA produce the mission/task analyses and workload predictions for the MH-60K and MH-47E aircraft.

Research Objectives

The overall objective of this research area is to determine the impact that high technology modifications are likely to have on the workload of MH-60K and MH-47E crewmembers. Specifically, the research is designed to:

- provide a mission/task analysis of the UH-60A and the MH-60K,

- determine the impact that the proposed MH-60K modifications will have on crew workload,
- provide a mission/task analysis of the CH-47D and the MH-47E, and
- determine the impact that the proposed MH-47E modifications will have on crew workload.

Method

The approach selected for meeting the research objectives is a refinement of the workload prediction methodology employed during the LHX research (Aldrich, Szabo, & Craddock, 1986) and the AH-64A research (Szabo & Bierbaum, 1986). The research is divided into four projects.

- In previous research, a baseline mission/task analysis of crew workload was conducted for the UH-60A helicopter, and a computer model of UH-60A workload was developed.

- Currently, a baseline mission/task analysis of crew workload is being conducted for the CH-47D helicopter, and a computer model of CH-47D workload is being developed.

- In a related research project, the UH-60A workload prediction model will be exercised to predict the impact that various MH-60K design modifications are likely to have on crew workload.

- In another related research project, the CH-47D workload prediction model will be exercised to predict the impact that MH-47E design modifications are likely to have on crew workload.

Status

The development of the UH-60A workload model was completed during the first contract year and was reported in the 1987 Annual Summary Report (Aldrich & McAnulty, 1987) and in a research product by Bierbaum et al. (1987).

CH-47D Task Analysis and Workload Prediction Model

The development of the CH-47D workload model was completed during the current contract year. During the next contract year, a technical report will be prepared that

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describes the task analysis and the development of the CH-47D workload prediction model. The completed project tasks are described briefly below.

Develop a mission scenario. This section describes the mission scenario that was developed in the CH-47D analysis. The CH-47D mission begins in an assembly area (AA). The pilot flies contour flight from the AA to a pick-up zone (PZ), where cargo and/or troops are assembled for pick up. After completing loading operations, the pilot flies nap-of-the-earth (NOE) to the landing zone (LZ) to insert the combat troops or deliver the cargo. After completing the delivery, the pilot flies NOE to the PZ for another load. This pattern is continued until refueling is required. The pilot then flies NOE from the LZ to the forward area arming and refueling point (FARP), where refueling operations are conducted. Upon completion of the FARP operations, the crew returns to the PZ for continuation of the mission. When the mission is completed, the pilot flies contour back to the AA. Preflight and postflight activities are not included in the analysis.

Divide the mission scenario into mission phases. The mission scenario was divided into the following nine phases:
- Departure (AA),
- Enroute (AA-PZ),
- Departure (PZ),
- Enroute (PZ-LZ),
- Departure (LZ),
- Enroute (LZ-PZ) or (LZ-FARP),
- FARP Operations,
- Enroute (FARP-PZ), and
- Enroute (PZ-AA).

Divide the mission phases into segments. The nine mission phases were divided into 37 unique segments. Some segments are used in more than one of the mission phases. The number of segments in each mission phase is listed below:
- Departure (AA-PZ) - 4,
- Enroute (AA-PZ) - 10,
- Departure (PZ) - 7,
- Enroute (PZ-LZ) - 12,
- Departure (LZ) - 3,
- Enroute (LZ-PZ) or (LZ-FARP) - 10,
- FARP Operations - 5,
- Enroute (FARP-PZ) - 10, and
- Enroute (PZ-AA) - 10.

Divide the segments into functions. Each of the 37 unique segments was divided into functions. A total of 66 unique functions was identified, alphabetized, and assigned a numerical identification code.

Identify the specific tasks for each function. Each of the 66 functions was divided into tasks. A total of 154 unique tasks was identified, alphabetized by object, and assigned a numerical identification code.

Identify the subsystems associated with each task. Seventeen aircraft subsystems were identified on the CH-47D. The subsystems are divided into the five major categories listed below:

- Engine,
- Flight Control,
- Navigation,
- Utility, and
- Visual

Estimate the workload for each task. A short verbal description of each of the workload components was written for each task. The descriptors were then compared to verbal anchors contained in 7-point rating scales designed for rating each of the five workload components. The verbal descriptions and ratings were reviewed by CH-47D subject matter experts (SMEs).

Estimate the time required to perform each task. The CH-47D simulator was not available for empirically recording task times during this project. Therefore, the time assigned to each task was developed from SME estimates. The SMEs estimated the times based upon their experience in performing the tasks.

Develop and exercise the CH-47D model. The specific tasks identified during the analysis were entered into data files for the workload prediction model. The researchers developed decision rules required to combine specific tasks into functions and to combine the functions into segments. All decision rules were then programmed and the workload prediction model was exercised to provide estimates of workload at each half-second interval for each of the 37 segments in the analysis.

MH-60K Task Analysis and Workload Prediction Model

During the current contract year, work progressed on the MH-60K task analysis and on the development of an MH-60K

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workload prediction model. The completed project tasks are
described briefly below.

Develop a mission scenario. This section describes the
mission scenario that was developed for the MH-60K analysis.
The MH-60K mission begins with a departure from a base site.
The pilot flies contour from the base to a rendezvous point,
where air-to-air refueling is accomplished. After refueling,
the pilot flies NOE from the rendezvous point to the LZ. The
pilot then flies back to a rendezvous point for refueling and
continues to the base. The complete mission is conducted at
night with night vision goggles. Preflight and postflight
activities are not included in the analysis.

Divide the mission scenario into mission phases. The
mission scenario was divided into five phases as follow:

- Departure (Base),
- Enroute (Base-Rendezvous),
- Enroute (Rendezvous-LZ),
- Enroute (LZ-Rendezvous), and
- Enroute (Rendezvous-Base).

Divide the mission phases into segments. The five
mission phases were divided into 14 unique segments. Some
segments are used in more than one of the phases. The number
of segments in each phase is listed below:

- Departure (Base) - 2,
- Enroute (Base-Rendezvous) - 4,
- Enroute (Rendezvous-LZ) - 4,
- Enroute (LZ-Rendezvous) - 4, and
- Enroute (Rendezvous-Base) - 3.

Divide the segments into functions. Each of the 14
unique segments was divided into functions. A total of 53
unique functions was identified, alphabetized, and assigned a
numerical identification code.

The following research activities are required to
complete the MH-60K task analysis and the development of the
MH-60K workload prediction model:

- identify the specific tasks for each function,
- identify the subsystems associated with each task,
- estimate the workload for each task,
- estimate the time required to perform each task,
- develop decision rules for the functions, and
- develop decision rules for the segments.

These tasks will be completed during the next contract year.
Upon completion of the tasks, all data will be entered into
data files, the MH-60K workload prediction model will be

developed, and the model will be exercised to predict the impact that the design modifications are likely to have on the MH-60K crew workload. A research report will be prepared to describe the task analysis, the development of the MH-60K workload prediction model, and the results from exercising the model.

MH-47E Task Analysis and Workload Prediction Model

During the current contract year, work also progressed on the MH-47E task analysis and on the development of an MH-47E workload prediction model. The mission scenario, mission phases, segments, and functions for the MH-47E are the same as those identified for the MH-60K.

The following research activities are required to complete the MH-47E task analysis and the development of the MH-47E workload prediction model:
- identify the specific tasks for each function,
- identify the subsystems associated with each task,
- estimate the workload for each task,
- estimate the time required to perform each task,
- develop decision rules for the functions, and
- develop decision rules for the segments.

Upon completion of these tasks, all data will be entered into data files, the MH-47E workload prediction model will be developed, and the model will be exercised to predict the impact that the design modifications are likely to have on the MH-47E crew workload. A research report will be prepared to describe the task analysis, the development of the MH-47E workload prediction model, and the results from exercising the model.

References

Aldrich, T. B., & McAnulty, D. M. (Eds.) (1987, November). Human factors research in aircrew performance and training. Annual summary report (ASI690-304-87). Fort Rucker, AL: Anacapa Sciences, Inc.

Aldrich, T. B., Szabo, S. M., & Craddock, W. (1986). A computer analysis of LHX automation options and their effect on predicted crew workload (Draft Technical Report ASI479-063-85[B]). Fort Rucker AL: Anacapa Sciences Inc.

Bierbaum, C. R., Szabo, S. M., & Aldrich, T. B. (1987, December). <u>Task analysis of the UH-60 mission and decision rules for developing a UH-60 workload prediction model</u> (ASI690-302-87, Vols. I, II, III, and IV). Fort Rucker, AL: Anacapa Sciences, Inc.

Szabo, S. M., & Bierbaum, C. R. (1986, October). <u>A comprehensive task analysis of the AH-64 mission with workload estimates and preliminary decision rules for developing an AH-64 workload prediction model</u> (Technical Report ASI678-204-86, Vols. I, II, III, and IV). Fort Rucker, AL: Anacapa Sciences, Inc.

DEVELOPMENT AND VALIDATION OF THE AH-64A
WORKLOAD PREDICTION MODEL

Dr. David B. Hamilton and Dr. Sandra M. Szabo,
Project Directors

Background

The Army's Air/Land Battle 2000 scenario presents a high-threat environment that will place heavy workload demands on combat helicopter operators. To increase mission effectiveness in this environment, the latest Army helicopters have been equipped with advanced technology. This technology includes electronic sensor capabilities that increase both the amount and fidelity of information available to the operators.

The AH-64A attack helicopter is equipped with the most advanced technology of any helicopter in the U.S. Army inventory. It is the first Army aircraft equipped with flight and weapon systems that allow missions to be conducted at night and under adverse weather conditions. However, the increased mission capabilities of the aircraft have dramatically increased the amount of information that the operators must process. The AH-64A is equipped with automated flight and combat (acquisition, targeting, and engagement) technology that is intended to reduce crew workload. In some instances, however, the tasks required to use the technology have either increased workload or simply changed the nature of the task without decreasing workload. High workload, in turn, reduces mission effectiveness, increases system manning requirements, and increases the training necessary for acquiring and maintaining flight proficiency.

One of the reasons that technology has failed to reduce operator workload in current Army aircraft is that human factors concepts were not adequately considered during the early stages of system design. In the past, no methodology existed for assessing the workload demands of emerging aviation/weapon systems prior to their development. Recently, however, researchers from the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) and Anacapa Sciences developed a methodology for predicting the workload demands placed on the crewmembers by the advanced technology proposed for the light helicopter family (LHX) aircraft. The methodology for predicting LHX workload in advance of system development can be extended to existing weapon systems.

The methodology's multidimensional view of human capabilities provides a unique opportunity for the system engineer to identify modifications that shift operator workload from one domain to another. For example, technology designed to reduce an aviator's need to maintain physical control of system functions often increases the aviator's role as a monitor. Thus, advanced technology may decrease operators' psychomotor workload and increase their cognitive workload. Given the limited capacity of human cognitive ability, system designers must avoid shifting all the workload associated with aircraft operations into the cognitive domain (or any other single domain, for that matter). Thus, this methodology, with its second-by-second estimate of operator workload, will allow the systems engineer to better utilize all the operators' capabilities and, in turn, increase system effectiveness.

Need

As part of its aviation Product Improvement Program, the Army is currently considering modifications to the AH-64A helicopter. The Aviation Systems Command (AVSCOM) requested that ARIARDA adapt the LHX workload prediction methodology to the AH-64A system to assess the effect that the proposed modifications will have on operator workload. In response to AVSCOM's request for support, ARIARDA tasked Anacapa to conduct the required research.

Research Objectives

The primary objective of the AH-64A workload prediction research is to determine the effect that advanced technology is likely to have on the workload of AH-64A crewmembers. Specifically, the research is designed to:

- determine the operator workload for the current configuration of the AH-64A aircraft,
- identify the AH-64A mission functions and subsystems for which design modifications will be most beneficial in reducing crew workload, and
- predict the effect that specific design modifications will have on crew workload.

The workload predictions yielded by the methodology will provide an objective assessment of the crewmember workload in the current configuration of the AH-64A aircraft and provide a workload criterion for evaluating proposed development of the helicopter. This input should be valuable in improving

the human-systems interaction, and thus improve mission performance.

Research Approach

The research for meeting these objectives has been divided into three projects:

- development of a model to predict AH-64A crewmember workload,
- validation of the AH-64 model, and
- assessment of the workload effects of AH-64A modifications.

In previous research, a comprehensive mission/task/workload analysis was conducted for AH-64A crewmembers. The results of the mission/task/workload analysis will be used to develop a computer model for predicting baseline AH-64A crew work-load. The workload predictions yielded by the model will then be validated. Finally, the computer model will be exercised to predict the effect that design modifications are likely to have on crew workload for various aircraft configu-rations. Each of the projects is described more fully below, following a brief description of the work completed under the previous contract.

Background

In previous research, a comprehensive task/workload analysis of all phases of the AH-64A attack mission was conducted. A composite mission scenario was developed from five mission profiles that assumed optimal flight conditions. In the composite scenario, the pilot's primary function was to fly the aircraft and the gunner's primary function was to acquire and engage targets. No reconnaissance or team leader functions were performed by the crew. During the analysis, 7 mission phases were identified and divided into 52 unique mission segments. The segments were further divided into 159 unique functions with 688 individual tasks necessary to the mission. The subsystem, crewmember, and time for each task was recorded. The results of the AH-64A analysis were described in a draft technical report by Szabo and Bierbaum (1986).

Development of the AH-64 Workload Prediction Model

The development of a computer model to predict workload for the crewmembers in the current configuration of the

AH-64A is the first project in this research area. The principal tasks in developing the model are:

- establish computer files for the mission/task/workload analysis data,
- develop function and segment decision rules,
- write computer programs to produce estimates of workload for the AH-64A baseline configuration, and
- review the model's behavior for validity and correctness.

Each of these tasks is described briefly below.

The initial task in this project will be to enter the mission/task/workload analysis data into a computer data base. This computer data base, when combined with the function and segment decision rules, will form the input to the computer model for AH-64A workload predictions.

For each of the 159 unique functions, a function summary sheet will be developed to identify the specific tasks performed by each crewmember. Function decision rules will be written to identify the sequence and time for the performance of these tasks. Following the development of the function summary sheets and decision rules, segment summary sheets and decision rules will be written. The segment decision rules will specify the procedure (sequence and time) for combining the functions, created by the function decision rules, to form each mission segment.

To permit an automated analysis of workload, computer programs will be developed to implement the decision rules. The mission/task analysis conducted during the previous contract used a top-down approach in which the tasks were identified as the basic elements of the mission. The computer model developed during this project will use a bottom-up approach in which the tasks (contained in the computer files) are combined to form functions which, in turn, are combined to form segments. The time-based function and segment decision rules are the blueprints for placing the tasks performed by each crewmember at the appropriate point on the mission timeline. These computer programs will simulate the sequence of tasks that each crewmember must perform to accomplish the mission. From this simulation the program will generate total workload estimates for each of the five workload components by summing the individual workload ratings for all the tasks that are currently being performed. Total component workload predictions will be generated for every half-second interval in the segment.

After the computer programs are written, the model can be exercised to produce estimates of total workload associated with the performance of concurrent, as well as sequential tasks in the AH-64A baseline configuration. The estimates of total workload for each workload component (i.e., visual, auditory, kinesthetic, cognitive, and psychomotor) will identify points on the mission timeline at which excessive workload, referred to as "overload," will occur. Four different indexes of overload have been identified and will be computed by the program.

After the computer model is exercised, any mistakes made in creating the task/workload analysis data base will be identified and corrected. The exercise of the model will produce the first look at the results of the dynamic combination of tasks and functions to form segments in the model. This computer simulation of the crew members' actions during each mission segment will then be reviewed by subject matter experts to ensure that the model conforms with typical crewmember actions.

Validation of the AH-64A Workload Prediction Model

During the second project, the AH-64A workload prediction model will be validated. Validation of the model will consist of these major steps:

- evaluation of the reliability of the workload component rating scales and the workload predictors used in developing the model,
- validation of the overall workload predictions yielded by the model, and
- refinement of the model.

Evaluation of the use of the workload component rating scales will be accomplished by determining (a) the interrater reliability for the rank order of the verbal anchors within each 7-point scale, and (b) the interrater reliability for assigning the numerical ratings to the verbal descriptors of workload.

Validation of the overall workload predictions yielded by the model will be established by conducting part-mission and full-mission simulation research. In each instance, predictions of workload for specific tasks will be compared with objective measures of primary and secondary task performance and subjective measures of workload such as the Subjective Workload Assessment Technique ratings (Reid, Shingledecker, & Eggemeier, 1981) or the NASA Task Load Index ratings (Hart & Staveland, 1987). The results of the validation investigations of both the rating scales and the

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workload predictions will subsequently be used to refine the
model.

Workload Analysis in Support of AH-64A Development

During this project, the AH-64A computer model will be
exercised to predict how crew workload might be affected by
proposed modifications to the aircraft. The project consists
of the following steps:
- identify the automation options proposed,
- conduct a task/workload analysis for each option,
- exercise the model to yield revised estimates of
  workload, and
- compare the estimates of workload for the baseline and
  automated configurations.

The results of this project can be used to estimate the
effects of the proposed automation options on the workload of
the crewmembers. These estimates, in turn, will assist
design engineers in determining the optimal configuration for
the aircraft.

Results

Work Completed

During the first year of the current contract, both the
mission/task/workload analysis and the decision rules were
extensively reviewed and revised. In addition, a preliminary
version of the computer model, using a Perkin-Elmer mini-
computer and FORTRAN language, was developed. The model was
exercised to produce preliminary analyses of workload for
each of the mission segments.

During the current contract year, a general mission/
task/workload analysis software system was developed using a
Zenith microcomputer and Turbo Pascal (see Development of a
Task Analysis/Workload (TAWL) Software System, pp. 11-14 of
this report). This task analysis/workload software system
was developed and refined in support of this project and
other projects currently being conducted by Anacapa
researchers.

During the current contract year, the AH-64A workload
model also was exercised to produce mission segment print-
outs. These printouts were reviewed to make certain that the
computer model accurately simulated the function and segment

decision rules. In some cases, the function and segment decision rules were revised.

Work Projected

During the next contract year, the revised model will be exercised to produce estimates for each of the 52 unique mission segments. These predictions will be reviewed to produce a final baseline version of the model. Results will be fully described in a research report. The previously produced draft technical report (Szabo & Bierbaum, 1986) will be revised to reflect the final version of the model.

A research plan for validating the model will be developed and submitted to ARIARDA for approval. Upon ARIARDA approval of the research plan, the validation research will begin. As the refinement of the model continues, the model will be used to assess the effect of proposed AH-64A modifications on operator workload.

References

Hart, S. G., & Staveland, L. E. (1987). Development of a NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. S. Hancock & N. Meshkati (Eds.), Human mental workload. Amsterdam: Elsevier.

Reid, G. B., Shingledecker, C. A., & Eggemeier, F. T. (1981). Application of conjoint measurement to workload scale development. In R. C. Sugarman (Ed.), Proceedings of the 25th annual meeting of the Human Factors Society (pp. 522-526). Santa Monica, CA: Human Factors Society.

Szabo, S. M., & Bierbaum, C. R. (1986). A comprehensive task analysis of the AH-64 mission with crew workload estimates and preliminary decision rules for developing an AH-64 workload prediction model. (Technical Report ASI678-204-86, Vols. I, II, III, and IV). Fort Rucker, AL: Anacapa Sciences, Inc.

SURVEY OF HUMAN FACTORS MODELS AND METHODOLOGIES FOR IMPROVING MAINTAINABILITY DESIGN

Dr. John W. Ruffner, Project Director

Background

Increasingly complex aviation systems are being developed to enhance the ability of Army aviators to fight and survive on the modern battlefield. However, these systems are often designed with little regard for the mental and physical capabilities and limitations of the soldiers who are required to operate and maintain them (Neal, Robinson, Takacs, & Rainwater, 1986).

Some progress has been made in designing aviation systems to be consistent with the capabilities and limitations of the operator; however, comparatively little attention has been paid to designing systems to improve their maintainability. Traditionally, the maintainability of a system is given the lowest priority during the design process, with maintainability being secondary to performance, cost, and operability criteria. By the time maintainability problems are identified, changes for the sake of efficient maintenance are often not feasible (McDaniel & Askren, 1985). Furthermore, efforts to increase system performance and operability often result in added system complexity, with a concomitant increase in maintenance requirements.

Maintenance costs are often the most important element in the life-cycle cost estimates for an aviation system. A typical breakdown is approximately 15% for design, 35% for production, and 50% for operation and support (Bond, 1987). The proportion of the Department of Defense annual budget required for maintenance has been estimated to be between 25% and 30%. Furthermore, the total maintenance costs of a piece of equipment throughout its life cycle are often expected to exceed its acquisition costs (Christensen & Howard, 1981).

Smith, Westland, and Crawford (1970) conducted a comprehensive review of the maintainability literature available at the time. They noted that the problem of maintaining military equipment in a state of readiness had grown to enormous proportions from 1950 to 1970, and that the dominant cause of the maintenance problem was the progressive and rapid increase in equipment complexity. In a more recent review, Bond (1987) concluded that the situation had not improved since that time, and that a "persistent maintenance crisis" presently exists in the military.

This situation is exacerbated by the projected shortfall in the number of military-aged individuals who will be available for maintaining complex aviation systems. The personnel who will be recruited into the military services in the next 20 years will be fewer in number and of lesser capabilities, aptitudes, and competencies than at present. The military services will have to compete with the civilian job market for the most capable individuals (Malone, Heasly, Waldeisen, & Hayes, 1986). In addition, only a small percentage of military technicians serve more than a 3- or 4-year enlistment period. This makes it extremely difficult for the majority of maintenance technicians to achieve the skill level required to maintain complex aviation systems.

Smith et al. (1970) identified three potential solutions to the problem of adequately maintaining complex military systems: (a) improve technician skills through training, (b) improve troubleshooting aids, and (c) improve equipment design. Prior to the mid-1960s, the predominant emphasis was placed on improving technician skills, with secondary emphasis on performance aids. Little, if any, attention was paid to improving equipment design.

As Cunningham and Cox (1972) noted, until equipment complexity became overwhelming, training was considered the most effective method of minimizing the time for system maintenance. In 1970, Smith et al. argued that efforts to provide better training were not succeeding in reducing the maintenance problem. Inadequate training was especially evident for troubleshooting problems that account for more than 60% of corrective maintenance time in electronic equipment.

To improve the maintainability of equipment while compensating for lower technician skill levels, maintenance technicians were supplied with improved troubleshooting aids (e.g., written procedural guides, built-in test equipment, automatic test equipment). However, periodic surveys have indicated that there have been negligible increases in the effectiveness of troubleshooting manuals. Even the most accurate built-in test equipment and automatic test equipment miss 5 - 10% of system faults, thus requiring manual troubleshooting. There still is an unacceptably high number of false alarms and unnecessary replacement of functioning equipment, resulting in time wasted in unnecessary maintenance actions and increased loads on the rest of the logistics system (Maxion, 1984; Coppola, 1984).

Smith et al. (1970), Crawford and Altman (1972), and Potempa, Lintz, and Luckew (1975), among others, strongly emphasized the need to improve maintainability by influencing

the design of systems as early as possible during the acquisition process. They stated that (a) equipment design is the most important factor contributing to the level of maintainability, and (b) there is a pressing need for data, methods, and models that specify human factors inputs to the engineer during system development.

More recently, the Department of Defense MIL-STD-470A (1983) stated that manpower and personnel shortages are of such magnitude that the maintainability problem must be approached through the design process as well as through the more traditional approaches of improving training and providing job performance aids. One of the primary objectives of the Army's Manpower and Personnel Integration (MANPRINT) program is to influence the design of military systems so that they can be operated and maintained in the most cost-effective and safest manner consistent with the manpower structure, personnel aptitude and skill, and training resource constraints of the Army (Department of the Army, 1987).

Need

As noted above, little progress has been made in increasing the maintainability of systems through improvements in training or job performance (e.g., troubleshooting) aids. Several sets of maintainability guidelines have been developed and published in the last 30 years (e.g., Folley & Altman, 1956; Department of Defense, 1984), but their content cannot be applied during systematic evaluations of various design variables. In addition, there is little data upon which quantitative maintainability trade-offs can be calculated between equipment designs.

In response to the Army's MANPRINT initiative, several models and procedural methodologies for applying knowledge about the capabilities and limitations of human operators and maintainers to the design of military systems have been developed or modified. The majority of this work has been directed toward the role of the human as system operator rather than as system maintainer. There is a mounting body of evidence indicating that models and procedural methodologies are needed that can be applied toward improving the maintainability of aviation systems as early as possible in the system design and acquisition processes.

Project Objective

The objective of this project is to identify human factors models and methodologies that may be used to improve the maintainability design of emerging Army aviation systems.

Project Status

Work Completed

Work on this project commenced in December, 1987. The project director conducted a search of (a) the National Technical Information Service and the Defense Technical Information Center data bases, and (b) the cumulative indexes for selected scientific publications. As a result of this search, approximately 100 documents were identified that are relevant to the topics of aviation maintenance and maintainability design. These include maintainability engineering textbooks, maintainability guidelines, military standards and handbooks, Army regulations, field manuals, technical manuals, literature reviews, technical reports, journal articles, and papers presented at professional meetings.

Work began on writing a draft report during June, 1988. An outline of the report was reviewed and approved by the Army Research Institute Aviation Research and Development Activity (ARIARDA) in July, 1988. The report is organized into four sections. The first section describes the background, purpose and scope of the survey. The second section presents a brief summary of Army aviation maintenance levels and tasks and an overview of previous maintainability design research. The third section presents a detailed summary of human factors models and methodologies that may be used to improve the maintainability design of emerging Army aviation systems. The fourth section identifies several key maintenance and maintainability design issues in Army aviation and presents recommendations for research to address these issues. At the end of the current contract year, a draft version of the first three sections of the report was completed.

Work Projected

A draft version of the report and an annotated bibliography summarizing the maintainability design literature reviewed for this project will be completed and submitted for formal ARIARDA review early in the next contract year. It is anticipated that after ARIARDA reviews the report, additional

research in the areas of aviation maintenance and maintain-
ability design will be planned and conducted.

References

Bond, N. A. (1987). Maintainability. In G. Salvendy (Ed.),
Handbook of human factors (pp. 1328-1355). New York:
Wiley & Sons.

Christensen, J. M., & Howard, B. S. (1981). Field experience
in maintenance. In J. Rasmussen and W. B. Rouse (Eds.),
Human detection and diagnosis of system failures (pp.
111-133). New York: Plenum Press.

Coppola, A. (1984). Artificial intelligence applications to
maintenance. In Denver Research Institute (Ed.),
Artificial intelligence in maintenance (pp. 23-44).
Brooks Air Force Base, TX: Air Force Human Resources
Laboratory.

Crawford, B. M., & Altman, J. W. (1972). Designing for
maintainability. In H. P. Van Cott and R. G. Kinkade
(Eds.), Human engineering guide to equipment design (pp.
585-631). Washington, DC: U.S. Government Printing
Office.

Cunningham, C. E. & Cox, W. (1972). Applied maintainability
engineering. New York: Wiley & Sons.

Department of Defense. (1984). Human engineering design
criteria for military systems, equipment and facilities
(MIL-STD-1472C). Washington, DC: Department of
Defense.

Department of Defense. (1983). Maintainability program for
systems and equipment (MIL-STD-470A). Washington, DC:
Department of Defense.

Department of the Army. (1987). Manpower and personnel
integration (MANPRINT) in materiel acquisition process
(AR 602-2). Washington, DC: Department of the Army.

Folley, J. D., Jr., & Altman, J. W. (1956). Guide to design
of electronic equipment for maintainability (WADC-TR-56-
218). Wright Patterson Air Force Base, OH: Wright Air
Development Center.

Malone, T. B., Heasly, C. C., Waldeisen, L. E., & Hayes, T. J. (1986). MANPRINT applications for design of advanced armored weapon systems. Proceedings of the 30th Annual Meeting of the Human Factors Society (pp 753 -757). Santa Monica, CA: Human Factors Society.

Maxion, R. A. (1984). Artificial intelligence approaches to monitoring system integrity. In Denver Research Institute (Ed.), Artificial intelligence in maintenance (pp. 257-273). Brooks Air Force Base, TX: Air Force Human Resources Laboratory.

McDaniel, J. W., & Askren, W. B. (1985). Computer-aided models to support ergonomics (AAMRL-TR-85-075). Wright-Patterson Air Force Base, OH: Air Force Aerospace Medical Research Laboratory.

Neal, D. L., Robinson, L. T., Takacs, S. P., & Rainwater, J. J. (1986). Be all that you can be: The Army's MANPRINT initiative. Proceedings of the Human Factors Society 30th Annual Meeting (pp. 769-770). Santa Monica, CA: Human Factors Society.

Potempa, K. W., Lintz, L. M., & Luckew, R. S. (1975) Impact of avionic design characteristics on technical training requirements and job performance. Human Factors, 17, 13-23.

Smith, R. L., Westland, R. A. & Crawford, B. M. (1970). The status of maintainability models: A critical review. Human Factors, 12, 271-283.

DESIGN AND APPLICATION OF FLIGHT SYMBOLOGY
Dr. Richard Weeter, Project Director

Background

The AH-64A attack helicopter is the first Army aircraft to feature the Pilot Night Vision System (PNVS). The PNVS is a display system designed to enable crewmembers to conduct attack missions at night and in adverse weather. A 40° horizontal by 30° vertical field of view is presented to the pilot's right eye by a 1-inch in diameter cathode ray tube mounted on the pilot's helmet. A set of 27 symbols can be projected onto this field of view, overlaid on external visual imagery produced by an infrared sensor. The symbology is intended to provide the pilot with critical flight and targeting information.

The PNVS symbology consists of 27 alphanumeric and shape-coded symbols. Many of the symbols are adaptations from traditional electromechanical flight instruments (e.g., the heading scale and lubber line). Some symbols appear at fixed locations on the displays. Symbols representing aircraft heading, airspeed, altitude, engine torque, and certain other basic flight information are constantly available on the display. Other symbols are dynamic representations of spatial information such as the projected center line of the aircraft. Such dynamic symbols may appear, disappear, and move on and off the display to reflect changes in aircraft or sensor orientation.

The pilot can select four subsets or operating modes of the PNVS symbology to reduce obscuration and make symbolic information more task-specific. Each mode adds symbology considered critical for performing a particular flight or weapons task to the basic flight information symbology.

Selection of the hover mode adds a velocity vector and an acceleration cue to aid the pilot in maintaining a hover. Selection of the transition mode adds a horizon line to the hover mode subset and is used when changing from a hover to cruise flight. Once cruise flight is established, selection of the cruise mode removes the velocity vector and acceleration cue but retains the horizon line in addition to the basic flight symbology. To aid the pilot in maintaining his position or in returning to a previous location and heading, the bob-up mode adds the velocity vector, acceleration cue, command heading, and hover position symbols to the basic flight information.

In 1977, Schmitt noted that little research had been accomplished that might contribute to an evaluation of symbology formats for aircraft visual displays. During the development of the AH-64A PNVS symbology, Buckler (1978a) described the state of research comparing different symbology formats as "sorely lacking." Furthermore, Buckler (1978b) reported that reconfigurable simulators were not readily available for testing alternative symbol designs. As a result, the PNVS symbology was designed largely on the basis of subject matter expert (SME) opinion. Buckler reported that SMEs (a) analyzed the information needed by the crew to perform representative AH-64A flight and weapons tasks, and (b) recommended the existing symbology format.

To date, no research has been conducted to evaluate whether the AH-64A PNVS symbols enhance or degrade information transfer during either routine or critical mission tasks. Nevertheless, the Department of Defense has established a military standard for symbology formats patterned after the current AH-64A PNVS symbology set (Department of Defense, 1984). Department of Defense officials intend to revise the military standard as data become available, implying that research could affect the design of future aircraft display symbology. However, Shrager (1977) suggested that the development of symbology may be more "evolutionary" than systematic. For example, symbology differing from the AH-64A PNVS symbology is currently being developed for the Army's MH-60K and MH-47E special operations helicopters (International Business Machines, 1988), but no information or empirical data have been released to explain how the new symbology set was developed or how it will affect crew performance. Schmitt (1982) cautioned that such "ad hoc integration" of display information creates potential flight safety hazards.

Problem

Currently, there is no widely accepted research methodology for addressing critical symbology design issues. Hence, there are no empirically valid design criteria for new aircraft display symbology. Moreover, there is no widely accepted research methodology for evaluating the efficiency of existing symbology sets. The first problem is to develop a methodology that can be used to evaluate the efficiency of the AH-64A PNVS symbology set.

The research methodology must address whether the symbol coding dimensions are compatible with the cognitive processes of AH-64A crewmembers. Ideally, successive experiments

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employing the methodology will culminate in the development of symbol and display format design criteria. The resultant symbology should (a) be compatible with known capabilities and limitations of aviators, (b) present information so that it can be interpreted accurately and efficiently, and (c) complemrnt rather than interfere with visual information available from the natural external visual scene and from sensor-provided imagery.

The Army Research Institute Aviation Research and Development Activity (ARIARDA) was tasked by the Army Aviation Systems Command to initiate research to meet these needs. Anacapa Sciences researchers began work on the project in February, 1987.

Project Objectives

The three objectives of this project are: (a) to develop a methodology for evaluating aircraft display symbology, (b) to conduct empirical evaluations of the existing AH-64A PNVS symbology, and (c) to identify potential design criteria for modifying the AH-64A PNVS symbology and for developing future aircraft display symbology.

Research Approach

Although experimental conditions and tasks vary widely, participants in selective visual attention experiments sometimes are required to perform visual tasks similar to those of pilots using aircraft visual displays (e.g., Lyon, 1987; Williams, 1982). Such experiments have revealed that a number of factors can affect attentional performance of visual tasks. For example, Eriksen and Hoffman (1972) demonstrated that the process of encoding information on visual displays is affected by the number, nature, and proximity of noise elements. Recently, Lyon (1987) suggested that the rapid attention shift component of selective visual attentica may be a measurable aspect of skilled performance in visicn-dependent tasks. These findings suggest that selective visual attention research may prove useful in evaluating aircraft visual display symbology.

Currently, a research plan is being developed for conducting selective visual attention experiments to evaluate the AH-64A PNVS symbology. The proposed research will investigate whether the selective visual attention research methodology can contribute to the development of evaluation and design guidelines for aircraft display symbology.

Project Status

Work Completed

At the close of the current contract year, project personnel were completing revisions to two documents. The first document is a literature review of factors that influence the design and evaluation of aircraft display symbology. The literature review emphasizes research that evaluates the effectiveness of symbology coding dimensions. The literature review also includes a bibliography of symbology references and a list of possible independent variables in symbology experiments.

The second document is a research plan that is being developed to address the project objectives within the constraints of available Anacapa and ARIARDA resources. As noted above, the theoretical basis of the research plan and the paradigms for the first experiments are drawn from the selective visual attention research literature. Two experiments designed to evaluate the current cueing procedure for the AH-64A PNVS Cued Line-of-Sight (LOS) symbol are described in the plan. The experiments are an initial attempt to develop an empirical method of evaluating visual display symbology.

To support the development of this research plan, project personnel duplicated portions of videotape recordings made by the AH-64A Video Recorder Subsystem (VRS). The recordings contain sequences of PNVS symbology in use under operational conditions. In addition, ARIARDA acquired an experimental workstation to support this research. The workstation consists of a Mitsubishi Diamond Scan monitor, an 80386 processor-based Zenith personal computer, and additional computer hardware (one 360K floppy disc drive, one 64K RAM cache card, one 4MB internal memory card, and one multi-function card). The experimental hardware has been installed and tested. Project personnel have started to develop the computer programs required to conduct the initial experiments.

Work Projected

Project personnel will complete revisions to both project documents. Once the research plan has been approved by ARIARDA, the experiments will be conducted. If results from the first two experiments indicate that the selective visual attention research methodology is successful, Anacapa

researchers will design a series of selective visual attention experiments to evaluate other AH-64A PNVS symbols. The experiments will increase in complexity, progressing from evaluations of individual symbols and procedures (e.g., the cueing procedure for the PNVS Cued LOS symbol) to evaluations of groups of symbols superimposed on actual PNVS visual imagery recorded from the AH-64A VRS.

References

Buckler, A. T. (1978a). A review of the literature on electro-optical flight displays (Technical Memorandum 3-78). Aberdeen Proving Ground, MD: Army Human Engineering Laboratory.

Buckler, A. T. (1978b). HEL participation in the plan for assisting in the definition of Army helicopter electro-optical symbology: An interim report (Technical Note 1-78). Aberdeen Proving Ground, MD: Army Human Engineering Laboratory.

Department of Defense. (1984). Human factors engineering design criteria for helicopter cockpit electro-optical display symbology (MIL-STD-1295A[AV]). Washington, DC: Department of Defense.

Eriksen, C. W., & Hoffman, J. E. (1972). Temporal and spatial characteristics of selective encoding from visual displays. Perception and Psychophysics, 12, 201-204.

International Business Machines. (February, 1988). Army Special Operations Forces - Integrated Avionics Subsystem System Design Review. Owego, NY: International Business Machines.

Lyon, D. (1987). How quickly can attention affect form perception? (AFHRL TR 87-28). Brooks Air Force Base, TX: Air Force Human Resources Laboratory.

Schmitt, V. P. (1977, October). The effects of a visual target indicator of search times (RAE TR 77152). Farnborough, England: Royal Aircraft Establishment. (AD B025 863L)

Schmitt, V. P. (1982, June). <u>Factors affecting the alloca-
    tion of attention and performance in cross-monitoring
    flight information displays</u> (RAE TM FS (F) 487).
    Farnborough, England: Royal Aircraft Establishment.
    (AD B069 792L)

Shrager, J. J. (1977). <u>Head-up displays: A literature
    review and analysis with an annotated bibliography</u>.
    Washington, DC: Department of Transportation, Federal
    Aviation Administration. (AD-A054 246)

Williams, L. (1982). Cognitive load and the functional field
    of view. <u>Human Factors</u>, <u>24</u>, 683-692.

NEW FAST DEVELOPMENT/VALIDATION

Dr. D. Michael McAnulty, Project Director

Background

The Army's original selection battery, the Flight Aptitude Selection Test (FAST), was developed in response to the unacceptably high attrition rates in the flight training program during the 1950s. The FAST comprised two overlapping batteries, one for commissioned officer (CO) applicants and one for enlisted and civilian applicants to the Warrant Officer Candidate (WOC) program. Each battery yielded a fixed wing and a rotary wing aptitude score for each applicant (Kaplan, 1965). The FAST, implemented in 1966, resulted in a substantial reduction in the flight training attrition rates.

In 1975, the U.S. Army Aviation Center requested a revision of the FAST that would produce a single, effective battery with fewer, shorter, and more reliably scored subtests (Eastman & McMullen, 1978). Factor analyses and multiple regression analyses were used to select 7 of the 12 FAST subtests for retention in the revised FAST (RFAST). Subsequently, item difficulties and item discrimination coefficients were analyzed to select the specific items to be retained in each subtest. The RFAST, implemented in 1980, is approximately one-half the length of the original FAST.

In subsequent research, Lockwood and Shipley (1984) found that 6 of the 7 subtests had adequate internal consistency and that the correlation between the RFAST score and performance in initial entry rotary wing (IERW) training was statistically significant. They concluded, however, that the low percentage of variance accounted for by the RFAST indicates the battery has limited utility in predicting IERW performance. In addition, Smith and McAnulty (1985) found that the RFAST has marginal retest reliability and that there was a large increase in the average score on retesting, indicating a need for an equivalent form for use when retesting is required.

Early in the development of a new FAST (NFAST) battery, research was conducted to identify the ability requirements for the successful completion of IERW training. Experienced IERW instructor pilots (IPs) were asked (a) to identify the tasks that are most indicative of successful performance in the primary and instrument phases of IERW, and (b) to judge the type and importance of the abilities that are required to perform each task. The task-ability ratings for each IP were

then transformed to a normally distributed, equal-interval scale using the method of successive intervals (McAnulty & Jones, 1984). Analyses of the transformed ratings indicated that 24 abilities in the psychomotor, perceptual, language, and cognitive domains were required for successful perfor-.ance in IERW. These analyses were used to design a test specifications matrix to guide the development of the NFAST (McAnulty, Jones, Cohen, & Lockwood, 1984).

Need

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has a continuing requirement to evaluate and improve the tests that are used to select applicants for the Army IERW training program. As indicated in the Background section, an NFAST battery is needed to improve the reliability and validity of the IEKW selection process and to provide an equivalent form to be used for retesting IERW applicants.

Project Objectives

The general objective of this project is to develop, evaluate, and implement a more effective battery of IERW selection tests. The specific technical objectives of the research project are to:

- develop experimental tests to measure the abilities required for successful IERW performance,
- develop two alternate forms of the NFAST battery,
- conduct pre-operational research to validate and equate the alternate forms of the NFAST battery,
- produce and implement the operational versions of the NFAST battery, and
- evaluate the NFAST battery and administrative proce- dures in operational use.

Research Approach

This project is a continuation of the ongoing ARIARDA research program in aviator selection and classification (McAnulty, 1986). The research is divided into three projects. In the initial project (NFAST Development), an experimental battery of aviation-related ability tests will be developed and administered to general population subjects. The data collected during the experimental administration will be analyzed to determine the psychometric characteris- tics of the new tests and the interrelationships among the

tests. The results of these analyses will be used to develop two alternate forms of an NFAST validation battery.

The second research project (NFAST Validation) will be a predictive validity investigation. The pre-operational validation research will be conducted to (a) determine the relationship between the NFAST tests, other predictor data, and performance in IERW training, and (b) equate the alternate forms of the battery on a large sample drawn from the target population of flight students. During this project, measures of IERW performance will be identified and evaluated as flight training criteria. The results of the validation analyses will be used to produce two alternate forms of an operational NFAST battery.

The third research project (NFAST Implementation) will be the implementation of the NFAST. All ancillary materials (machine scorable answer sheets, administrative manuals, scoring and equating manuals, selection criteria) will be developed and delivered for operational use. After the NFAST is implemented, a sample of field data will be analyzed to ensure that the psychometric characteristics of the operational battery are not significantly different from the validation battery. Finally, data will be collected and analyzed to ensure that the tests are being administered properly and that the test scores are being used appropriately in the selection process.

Project Status

Work Completed: NFAST Development

The NFAST Development project has been completed. Nine new tests were developed for the experimental NFAST battery. Eight tests were each designed to measure a unique ability and one test was designed to measure a complex of abilities required for the successful completion of IERW training. Four standardized tests were also included in the battery as marker variables. The 7-hour experimental battery was administered to 290 general population subjects at three military installations in the southeastern United States.

The results indicate that the complex ability test and six of the unique ability tests assess reliable individual differences in the abilities of interest. The average difficulty levels of the seven tests are near the optimum level of .50; the test variances indicate the measurement of substantial individual differences; and the estimates of reliability are acceptable when test length and the design

specifications are considered. The remaining two unique ability tests had undesirable psychometric characteristics or did not contribute any unique variance to the factor structure of the battery. A technical report (McAnulty, Cross, & Jones, 1986) that describes the results of this research was prepared and submitted to ARIARDA for review.

The research results were used to develop two alternate forms of the NFAST validation battery. Each form consists of modified versions of the complex test and the six unique ability tests that had acceptable psychometric characteristics. In general, the validation battery tests are approximately two-thirds the length of the experimental battery tests. The alternate forms of five of the tests have approximately 50% of the items in common. The complex ability test forms and one of the unique ability test forms do not have any identical items. Finally, a knowledge test of helicopter operations and aerodynamic principles was adapted from the RFAST battery for inclusion in the validation battery. The items on the knowledge test are identical on both forms. Each form of the validation battery requires approximately four hours to administer.

Work Completed: NFAST Validation

The NFAST Validation project activities are partially completed. Between March and October 1987, the alternate forms of the NFAST battery were administered to approximately 95% of the CO and WOC flight students during the first two weeks of IERW training. When the test administration phase was terminated, complete and usable test data were collected from 377 CO and 341 WOC students; 362 and 356 students took Form E and Form F of the battery, respectively.

Analyses of the test data indicate that the target population performance on the validation battery, excluding the helicopter knowledge test, is similar to the general population performance on the experimental battery. The average difficulty levels are near .50 despite the more restrictive time limits that were imposed on the validation tests, and the variances indicate that substantial individual differences in ability are being measured by the tests. The internal consistency estimates of reliability are also within an acceptable range. Performance on the two forms of the battery is very similar except for one of the unique ability tests. Test performance by the CO and WOC students is also quite similar, although the CO students scored significantly higher ($p < .01$) on four of the tests.

The test results on the helicopter knowledge test adapted from the RFAST indicate that the test is not difficult and that there is limited variability in the scores. WOC students scored significantly higher on the test than the CO students. However, there is no difference in performance by either student group on the two forms of the test. Since the test items are identical on both forms, this result indicates there was no systematic sampling bias in terms of aviation-related knowledge in the assignment of students to the alternate forms of the NFAST battery.

The collection of IERW performance measures is nearly completed. Academic test grades and end-of-IERW-phase flight checkrides are being collected from the Academic Records Division as the students complete training. Data are also being collected on the number of flight hours each student required to complete each phase of training. Finally, changes to the class rosters are being monitored to identify tested students who have been eliminated from training or who have moved to a different class. The reasons for these administrative changes (e.g., some setbacks may be due to student flight deficiencies and others may be due to a shortage of IPs) are also being recorded.

Work Projected: NFAST Validation

IERW performance data will be collected until all the students in the test data base have either graduated or attrited from flight training (approximately one year after the last battery administration). When the performance data base has been established, appropriate statistical analyses will be conducted to determine the psychometric characteristics of the performance measures, the interrelationships among the performance measures, and the correlations between the predictor and performance measures. Preliminary analyses ($n = 549$) indicate that a subset of tests from the NFAST battery will significantly improve the effectiveness of the selection procedures used for the IERW course. The results of the final analyses will be used to produce two alternate forms of the NFAST for operational use. The development of the operational batteries should be completed by April 1989.

Work Projected: NFAST Implementation

The NFAST Implementation project has not been formally initiated, although a prototype administration manual was developed for use with the validation battery. The administration manual will be modified for use with the

operational battery. Additional ancillary materials, such as
a scoring and equating manual and selection criteria
guidelines, will be developed. The operational batteries and
ancillary materials will be delivered to the U.S. Army
Soldier Support Center for implementation.

After the NFAST is in operational use, follow-on
research is planned to ensure that applicant performance on
the test batteries is within acceptable limits, that adminis-
trative procedures are being followed, and that the selection
criteria are valid. Depending on the results of the pre-
ceding research, it may be necessary to conduct a second
validation effort using an unrestricted sample (i.e., not
already selected for flight training) of IERW applicants.

References

Eastman, R. F., & McMullen, R. L. (1973). Item analysis and
revision of the flight aptitude selection tests (ARI
Field Unit Research Memorandum 78-4). Fort Rucker, AL:
Army Research Institute for the Behavioral and Social
Sciences. (AD A077 953)

Kaplan, H. (1965). Prediction of success in Army aviation
training (Technical Research Report 1142). Washington,
DC: Army Personnel Research Office. (AD A623 046)

Lockwood, R. E., & Shipley, B. D., Jr. (1984). Evaluation of
the Revised Flight Aptitude Selection Test (Technical
Report ASI479-020-84). Fort Rucker, AL: Anacapa
Sciences, Inc.

McAnulty, D. M. (1986). Development of a 1984-85 version of
the Army Flight Aptitude Selection Test. In K. D. Cross
& S. M. Szabo (Eds.), Human factors research in aircrew
performance and training (Final Summary Report ASI479-
080-86, pp. 61-66). Fort Rucker, AL: Anacapa Sciences,
Inc.

McAnulty, D. M., Cross, K. D., & Jones, D. H. (1986). The
development of an experimental battery of aviation
related ability tests (Technical Report ASI678-202-
86[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

McAnulty, D. M., & Jones, D. H. (1984). An evaluation of aviator training ability requirements scale ratings. In M. J. Alluisi, S. deGroot, and E. A. Alluisi (Eds.), Proceedings of the 28th Annual Meeting of the Human Factors Society (pp. 356-361). Santa Monica, CA: Human Factors Society.

McAnulty, D. M., Jones, D. H., Cohen, R. J., & Lockwood, R. E. (1984). Identification of the abilities required for effective helicopter training performance (Technical Report ASI479-046-84[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

Smith, R. L., & McAnulty, D. M. (1985). Test-retest reliability of the Revised Aptitude Selection Test (RFAST) (ARI Field Unit Draft Research Report). Fort Rucker, AL: Army Research Institute for the Behavioral and Social Sciences.

DEVELOPMENT OF A PEER COMPARISON PROGRAM

Dr. D. Michael McAnulty, Project Director

Background

This project was initiated in response to a request from the School Secretary, U.S. Army Aviation Center, Fort Rucker, Alabama, for support in developing an algorithm to select course honor graduates based on the "whole person" concept. The School Secretary wanted to augment the academic grade criterion used to select honor graduates in the Aviation Officer Advanced Course (AVNOAC), a five-month officer training course for captains and promotable first lieutenants. The purposes of the augmented program are:

- to motivate students to maximize their military and academic efforts during the course, and
- to identify students who have high potential as Army aviation officers at an early stage of their careers.

Specifically, the School Secretary was interested in using peer assessments by the AVNOAC students as a component in the honor graduate selection algorithm. The peer assessments were to evaluate aspects of the students' performance that were not reflected in their academic scores. Instructor ratings were not considered as a criterion component because of the limited interaction between the school cadre and the students.

Project Objectives

Following a review of the peer assessment literature and the AVNOAC syllabus, a peer comparison (PC) methodology was proposed for use in the AVNOAC. The School Secretary agreed to support the following research objectives:

- identify the most important military qualities that can be assessed by peers during the AVNOAC,
- develop the PC instruments and procedures for use in the AVNOAC, and
- experimentally evaluate the PC technique prior to implementation.

Research Approach

The research approach was divided into three phases that correspond to the research objectives. During Phase 1, a

military qualities survey was administered to identify the most important qualities that can be assessed by peers during the AVNOAC. The survey asks senior aviation officers to rate a list of primary military qualities as potential dimensions for evaluating student performance and for identifying students with high career potential. The survey data provide the information needed to develop the PC instruments.

During Phase 2, three project assessment instruments were developed: the PC form to be completed by the class members to evaluate their peers, a faculty advisor rating (FAR) form to be completed by each class member's training officer, and a student critique to be completed by the students to evaluate the PC instruments and procedures. During Phase 3, the PC technique was administered and evaluated.

Project Status

Work Completed

Phase 1: Military qualities survey. Following a search of the literature and a review of current Army student evaluation dimensions, definitions of 14 primary military qualities (e.g., adaptability, initiative, judgment, leadership, and responsibility) were compiled for evaluation by senior aviation officers. Several important military qualities were excluded from the survey because they are evaluated by academic scores or are unlikely to be demonstrated during the AVNOAC. Sixteen senior Army aviation officers were asked to rate each quality on the following four scales:

- importance to the performance of captains,
- importance to the performance of senior officers,
- probability of demonstration during the AVNOAC, and
- degree of overlap with the other qualities.

Eleven surveys were completed and returned. Three of the qualities (leadership, judgment, and responsibility) had consistently high ratings and were selected as PC dimensions. Seven of the qualities were clearly perceived as being inappropriate PC dimensions. Appearance and cooperation were selected from the remaining four qualities as two additional PC dimensions.

Phase 2: Form development. Three research forms were developed for use in this project. The PC form was developed from (a) the results of the military qualities survey, (b) a combination of the peer nomination and peer ranking techniques (e.g., Kane & Lawler, 1978), and (c) the psychophysical method of paired comparisons (Engen, 1971). On the

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PC form, each section member (a class is divided into two sections) is required to nominate and rank order five peers on the basis of their potential as Army aviation officers. The section member then makes paired comparisons of the nominees on the five military qualities that were selected from the military qualities survey.

PC scores are computed for each peer by first summing the rank score (five points for first rank, four points for second rank, ..., one point for fifth rank) from each nominating section member. The summed rank scores are then added to the number of favorable comparisons the peer received on each military quality. Finally, the total is divided by the maximum possible score to enable direct comparisons between sections with unequal numbers of students. The PC scores can range from 0.0 (no nominations) to 1.0 (ranked first by all section members and always favorably compared with the other nominees). Because each section member nominates five peers out of approximately 50 students, a PC score greater than .20 probably represents a consensus among the section members that the student has high potential as an Army aviation officer.

A FAR form was developed to obtain independent evaluations of the students' potential as Army aviation officers. Each AVNOAC faculty advisor usually supervises six or seven students. On the FAR, the advisors estimate the officer potential of their students by assigning them percentile ranks in an average group of 100 captains.

Finally, a student critique form was developed to ascertain student attitudes toward the peer comparison program. The students are asked to rate the fairness, utility, aversiveness, and difficulty of various aspects of the program. They are also asked to express their opinions about the implementation of the program and to offer recommendations for improving the program.

Phase 3: Experimental administration 1. Peer comparisons were collected on an experimental basis (i.e., the PC scores were not used to select honor graduates) from Sections 1 ($n = 38$) and 2 ($n = 40$) of AVNOAC 85-2 in July 1985. A second set of PC ratings and the student critiques were collected from Section 1 ($n = 33$) and Section 2 ($n = 28$) approximately one month later. The faculty advisors completed the FARs immediately after graduation. In addition, the final academic averages (AVGs) were obtained from the School Secretary's offi e.

The scores for the first and second data collections were highly correlated (Section 1 = .96 and Section 2 = .86), indicating the stability of the ratings over time. Because of the high correlations, the ratings from the two data collections were combined into a single PC score for each peer. The PC scores ranged from .00 to .48 in Section 1 and from .00 to .36 in Section 2. Four peers in Section 1 and three peers in Section 2 received PC scores greater than .20. A majority of the PC scores in both sections were between .00 and .05. The scores indicate a high consensus among the members of the class in identifying peers with the highest potential as aviation officers.

The PC scores were then correlated with the FARs and AVGs. For Sections 1 and 2, respectively, the PC correlations are .45 and .33 with the FAR, and .55 and .30 with the AVG. These correlations are sufficiently high to show an expected relationship between observations of the same individuals. At the same time, the correlations are sufficiently low to indicate that the PC score is measuring a unique perspective of the class members. The correlations between the FAR and AVG are .76 and .59 in Sections 1 and 2, respectively. This result probably indicates that the faculty advisors were depending upon the academic average as a primary source of information in making their ratings.

Finally, the responses to the PC critique were tabulated. The overall reaction of the class members to the PC program was negative: a majority indicated that the PC was very biased, slightly or not at all useful, and slightly or not at all predictive of future performance. Furthermore, 72% of the respondents were either very or extremely unfavorable toward any potential implementation of the program. The responses to the other critique items reflected combinations of positive, negative, and neutral attitudes, without any attitude representing a majority opinion.

The results of the first administration indicated that the PC technique was a potentially useful procedure for identifying the class members with the highest potential as Army aviation officers, although the students were critical of its use. There were, however, several problems with the first administration. First, the students were not advised about the PC program before the experimental administration. Second, a concurrent but surreptitious attempt by the class leaders to evaluate the section members was discovered just before the second data collection. Both of these problems may have affected the students' attitudes about class evaluations. Finally, the period of time that elapsed between the first and second PC administrations was too short to evaluate the stability of the peer assessments.

Phase 3: Experimental administration 2. The second
experimental administration was designed as a replication of
the first administration, with the following changes:
- students were advised in advance of the research,
- other non-academic evaluations were prohibited,
- three months elapsed between the initial and final
  data collection,
- the military quality definitions were modified
  slightly,
- the order of presentation of the military qualities
  and nominee pairs was completely counterbalanced, and
- a new roster coding system was instituted to protect
  student privacy.

In December 1985, usable PC ratings were collected from
48 students in Section 1 and 48 students in Section 2 of
AVNOAC 86-1. In March 1986, 47 students in Section 1 and 44
students in Section 2 completed usable PC ratings and student
critiques. FARs were completed by most of the faculty
advisors shortly after graduation and the AVGs were collected
from the School Secretary's office.

Two types of reliability coefficients were computed on
the AVNOAC 86-1 ratings. First, the correlations between the
initial and final ratings are .79 in Section 1 and .93 in
Section 2, indicating the stability of the ratings across a
period of approximately three months. Second, split-half
(odd-even) correlations for each data collection for each
section were computed to evaluate the internal consistency of
the ratings. The correlations are .71 and .76 for Section 1,
and .93 for both data collections for Section 2. The relia-
bility coefficients are acceptable in all cases, although
they are obviously higher in Section 2. Because of the high
correlations, the ratings from the two data collections were
combined into a single PC score for each peer in each
section.

The PC scores ranged from .00 to .24 in Section 1 and
from .00 to .47 in Section 2. Four peers in Section 1 and
two peers in Section 2 received PC scores greater than .20.
As in class 85-2, a majority of the PC scores in both sec-
tions were between .00 and .05. The scores indicate a high
consensus among the members of Section 2 in identifying the
two peers (PCs = .42 and .47) with the highest potential as
aviation officers. The PC scores in Section 1 also distin-
guish the peers having the highest potential, even though the
PC scores are much lower. The lower scores could be an arti-
fact of the methodology if there are more than five peers
with high potential who are not substantially different from
each other.

The PC scores were then correlated with the FARs and AVGs. For Sections 1 and 2, respectively, the PC correlations are .02 and .30 with the FAR, and .24 and .27 with the AVG. These correlations indicate that the PC score is measuring a different aspect of the class members' performance during the AVNOAC. The .02 correlation between the FAR and PC in Section 1 is partially attributable to the highly skewed distribution of FARs. The correlations between the FAR and AVG are .53 in both sections. The FAR-AVG correlations probably indicate that the faculty advisors used the academic average as a source of rating information.

Finally, the PC critique responses from class 86-1 were negative overall, but not as negative as class 85-2. A majority of the 86-1 respondents indicated that the PC was either slightly or not at all useful for selecting AVNOAC honor graduates; the respondents were approximately evenly divided on the issues of PC fairness, bias, and predictability of future Army performance. Ratings of the adequacy of definitions and the difficulty of nominating, ranking, and comparing peers were very similar to the 85-2 results. Despite the slight positive shift in attitude toward the PC program, 69% of the respondents were still either very or extremely unfavorable toward any potential implementation of the program.

The results of the 86-1 data collection support the conclusion drawn from the 85-2 results: the PC technique is a potentially useful procedure for identifying the peers with the highest potential as Army aviation officers, at least in terms of the reliability of the ratings. There was a consensus identification of the peers with the highest potential and the ratings were generally consistent over a 3-month data collection interval. Longitudinal research is required to determine the validity of the PC technique for predicting future performance. Similar to the 85-2 students, the 86-1 students found the rating procedure to be aversive and were unfavorable toward the implementation of the PC technique.

Work Projected

Only one activity remains to be completed on the PC project. A report will be prepared to present the results of the research to the School Secretary's office. The report will include recommendations regarding the implementation of the PC program.

References

Engen, T. (1971). Psychophysics II: Scaling methods. In J. W. Kling and L. A. Riggs (Eds.), _Experimental psychology_ (3rd ed., pp. 51-54). New York: Holt, Rinehart, and Winston.

Kane, J. S., & Lawler, E. E., III. (1978). Methods of peer assessment. _Psychological Bulletin, 85,_ 555-586.

EVALUATION OF THE AVIATION RESOURCE MANAGEMENT SURVEY (ARMS) CHECKLIST

Dr. John W. Ruffner, Project Director

Background

According to the Army's "total force" concept, Reserve Component (RC) aviators serving in the U.S. Army Reserve (USAR) and the Army National Guard (ARNG) are required to train to the same standards and to maintain the same level of flight proficiency and flight safety as aviators serving in the Active Component. RC aviators must meet these requirements with limited resources. Therefore, the individuals who are responsible for planning, implementing, and evaluating RC training must manage the available resources (e.g., aircraft, training time, flying hours, instructor pilots) efficiently.

One of the ways that the Army helps RC training managers achieve efficiency is through evaluation visits from Aviation Resource Management Survey (ARMS) teams. U.S. Army Forces Command (FORSCOM) Regulation 350-3 (1984) states that the general purposes of the ARMS are to evaluate the management of unit aviation programs, to identify management practices that require improvement, and to provide staff assistance as necessary. As defined by FORSCOM, the ARMS has four specific objectives:

- to help commanders identify strengths and weaknesses in all aviation-related programs;
- to assess an aviation support facility's capacity to support the training of units assigned to the facility;
- to assess the aviation unit's capabilities (a) to operate safely, efficiently, and effectively, and (b) to maintain aviation resources apart from the support facility while accomplishing its mobilization mission; and
- to identify problems and coordinate assistance required to solve problems that are beyond the facility commander's or unit commander's sphere of authority.

The Deputy Chief of Staff for Training (DCST) in each of the five Continental U.S. Armies (CONUSAs) is responsible for conducting ARMS evaluations. According to FORSCOM Regulation 350-3 (1984), an ARMS is to be conducted at least once a year for each USAR facility and unit, and at least once every two years for each ARNG facility and unit within the CONUSA.

Problem

Each CONUSA has its own procedure for carrying out the ARMS evaluation program. There is a lack of standardization across the CONUSAs in (a) the functional areas (e.g., safety, standardization, and training) that are evaluated; (b) the procedures used by the ARMS teams to assess the facilities and units; and (c) the standards for acceptable performance.

The first U.S. Army DCST, Aviation Division, has developed a checklist to be used by the ARMS team during its evaluation visits. The checklist originally was published in October 1983, and republished in August 1985, as First Army Pamphlet 95-1. The checklist draws from two sources: (a) FORSCOM Form 14-1-R "Reserve Component Aviation Resource Management Checklist" (1980), and (b) the U.S. Army Safety Center "Guide to Aviation Resources Management for Aircraft Mishap Prevention" (1984).

The First Army checklist contains 670 items divided into the following 11 major functional areas of evaluation:
- Aviation Safety Management,
- Facility/Unit Operations,
- Aviation Standardization and Training,
- Aircraft/Flightline Operations,
- Aeromedical Management,
- Aircraft Crash Rescue and Fire Fighting,
- Petroleum, Oil, and Lubricants,
- Maintenance Management,
- Aviation Armament,
- Aviation Life Support Equipment, and
- Physical Security.

Each checklist item describes a specific deficiency that may result in (a) the failure of a facility to accomplish its mission of supporting its assigned RC units, or (b) the failure of a unit to accomplish its mobilization combat mission. The checklist items were written by aviation subject matter experts who are knowledgeable about (a) the operational requirements of RC support facilities in each of the functional areas, and (b) the mobilization mission requirements for RC units.

The DCST, First U.S. Army, has expressed concern about several problems with (a) the content of the checklist, (b) the manner in which the checklist items are used to evaluate RC facilities and units, and (c) the management and utilization of information obtained from ARMS visits. Consequently, during the second quarter of fiscal year 1985, the DCST requested that the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) provide research

support to evaluate and revise the checklist. Anacapa
Sciences began work on the project on 3 June 1985.

Project Objectives

The general objectives of the ARMS Checklist research
are:
- to perform a systematic evaluation of the content of
  the First U.S. Army ARMS Checklist,
- to develop a set of recommendations for improving (a)
  the ARMS checklist and (b) the procedures used to
  administer it, and
- to develop a computer-based information management
  system for organizing and analyzing ARMS checklist
  data.

Research Approach

A preliminary review of the ARMS Checklist indicated
that several deficiencies existed in the checklist and
administrative procedures:

- The ARMS Checklist is excessively long. There are
  many items that may not be highly related to mission
  success.

- The procedures used to evaluate checklist items and to
  combine ratings from the various functional areas into
  an overall rating are not standardized.

- The negatively stated item format does not allow an
  inexperienced evaluator to focus on the specific
  subject in the item to be evaluated.

- The items are not listed in an order that allows an
  inexperienced evaluator to proceed through the
  evaluation steps efficiently.

- The items are not identified as applying specifically
  to an aviation facility, an aviation unit, or both.

- Many items are too general to be associated with
  observable conditions or events.

- There is no systematic procedure for collating infor-
  mation about commonly occurring deficiencies observed
  across facilities/units during one year.

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The preliminary review led to the development of three criteria for determining if an item should be retained in the checklist. Specifically, an item should be retained in the checklist only if the attribute addressed in the item is: (a) easily detectable during an ARMS visit (Detectability), (b) important for judging the status of one of the functional areas (Importance), and (c) critical for mission success (Criticality). A survey questionnaire was developed to assess the extent to which the checklist items meet the three criteria for a support facility and for a unit. A separate version of the questionnaire was developed for each of the functional areas. The respondents for the questionnaire were aviators and aviation technicians from First Army National Guard and Army Reserve aviation support facilities and aviation units.

Project Status

Work Completed

Pretesting of the questionnaires was completed in November 1985. Following pretest and revision, the questionnaires were mailed to ARNG and USAR facilities in the First Army area. An average of 23 respondents completed a questionnaire in each functional area. Responses to the questionnaires were entered into a data base, verified, and analyzed. Preliminary results of the data analyses were briefed to the First Army DCST in June, 1986 and to staff members of the Aviation Division, DCST, First U.S. Army in March 1987.

The results indicate that the deficiencies described in the majority of the checklist items are detected easily during an ARMS evaluation visit and are moderately important for assessing the functional areas in which they are presently classified. The results also indicate that a facility or unit with the deficiencies described in the majority of the checklist items could support most aspects of its mission, assuming that the deficiencies exist in isolation. The results suggest that a single version of the checklist needs to be developed, with each item presented as an affirmative question instead of a negative statement and clearly annotated to indicate whether it applies to a facility or to a unit.

A set of decision rules was developed to aid the military user in determining if items should be retained in their present form, revised, or deleted from the checklist on the

basis of the item's Detectability, Importance, and Criticality ratings. The decision rules should be applied to both the facility and unit checklist item ratings. An information data base was developed (a) to summarize the checklist items' Detectability, Importance, and Criticality ratings, and (b) to record the performance of RC units on specific checklist items and functional areas during future ARMS evaluation visits. The data base was designed to enable the First Army ARMS team (a) to select items for retention, revision, or deletion using the decision rules, (b) to reorganize the checklist by grouping together items with similar content and reference publications, (c) to place the items in a sequence that minimizes evaluator effort, and (d) to utilize the data obtained from future ARMS visits more effectively (e.g., to identify commonly occurring deficiencies).

Near the end of the first contract year, a draft technical report describing the method and results was submitted to ARIARDA for formal review (Ruffner & McAnulty, 1987). The report is entitled "An Evaluation of the Aviation Resource Management Survey (ARMS) Checklist." ARIARDA completed its review of the draft report and returned it to Anacapa for revision during the current contract year. At the end of the current contract year, the revisions to the report are being completed.

Work Projected

Early in the next contract year, the revisions to the final report will be completed and the report will be submitted to ARIARDA.

References

First U.S. Army. (1985). Reserve component commander's guide – aviation standardization training program evaluation and aviation resource management survey (First Army Pamphlet 95-1). Fort Meade, MD: Department of the Army.

Ruffner, J. W., & McAnulty, D. M. (1987). An evaluation of the aviation resource management survey (ARMS) checklist (Technical Report ASI690-301-87[B], Vols. I and II). Fort Rucker, AL: Anacapa Sciences, Inc.

U.S. Army Forces Command. (1984). Specialized training in FORSCOM active component and reserve component units (Regulation 350-3). Fort McPherson, GA: Department of the Army.

U.S. Army Forces Command. (1980). Reserve component aviation resource management survey checklist (FORSCOM Form 14-1-R). Fort McPherson, GA: Department of the Army.

U.S. Army Safety Center. (1984). Guide to aviation resources management for aircraft mishap prevention. Fort Rucker, AL: Department of the Army.

DETERMINATION OF ARMY RESERVE COMPONENT TRAINING REQUIREMENTS

Dr. John W. Ruffner, Project Director

Background

Anacapa Sciences and U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) personnel have recently conducted research to determine the adequacy of time allocated to meet Army National Guard (ARNG) training requirements and to determine the military and civilian demographic characteristics of ARNG aviators. The results of the ARNG research are reported in detail by Szabo, Ruffner, Cross, and Sanders (1986) and Ruffner and Szabo (1986).

Like their counterparts in the ARNG, aviators in the U.S. Army Reserve (USAR) must meet the same annual training requirements as aviators in the active Army. The types of information obtained during the ARNG research are equally valuable for addressing training and personnel management issues in the USAR. Therefore, the First Army Deputy Chief of Staff for Training (DCST) requested that ARIARDA and Anacapa obtain demographic data and information about the adequacy of training requirements and training time for USAR aviators in the First Army area.

Project Objectives

The USAR aviation training requirements research has six specific objectives. The objectives are listed below:

- determine the demographic characteristics of the current First Army USAR aviator force (e.g., age, years of service, number of flight hours);
- determine the current career intentions of First Army USAR aviators;
- identify the factors influencing First Army aviators' decisions to join, remain in, or possibly leave the USAR;
- determine if the aviators consider the amount of time allocated for training to be adequate for meeting the requirements;
- determine the aviators' willingness to spend additional time to meet the training requirements; and
- identify the factors that may affect the First Army aviators' ability to utilize the allocated time to meet the training requirements (i.e., training obstacles).

Research Approach

The research approach adopted for this project is similar to that used for the ARNG project. The approach is described in detail in Szabo et al. (1986) and summarized in Ruffner (1987). Briefly, USAR aviators completed a questionnaire during a weekend drill period that assessed military and civilian demographic variables, adequacy of current training requirements, adequacy of the time allocated to meet the requirements, willingness to spend additional time to meet the requirements, and obstacles to training.

Project Status

Work Completed

Work began on the project in June, 1985. The aviator questionnaire that was used in the ARNG study was modified slightly to reflect minor differences that exist between the ARNG and USAR (e.g., types of units and aircraft). In addition, a few items were added to the USAR version of the questionnaire to obtain information of interest to the First Army DCST (e.g., extent of simulator utilization). The USAR aviator questionnaire was pretested in November 1985. The feedback obtained during the pretest visits was used to revise the questionnaire.

The questionnaire was distributed to the aviators in March 1987. A total of 139 questionnaires, representing 56% of the USAR aviators in the First Army area, was completed and returned to ARIARDA between April 1987 and June 1987. Data from the questionnaires were entered into a data base and verified. Descriptive statistics (i.e., means, standard deviations, medians, and percentages) were generated for each questionnaire item for the total sample and for subsamples of commissioned officers and warrant officers.

In December of the current contract year, a written summary of the data analysis results was published as Army Research Institute Working Paper FR/ARDA/ASI-88-1 (Ruffner & McAnulty, 1987). In general, the results of the survey are similar to the results of the ARNG survey (Szabo et al., 1986), with a few minor differences. The major results of the questionnaire data analysis are the following:

- First Army USAR aviators have somewhat lower experience levels (e.g., flight hours, time in service, percent with combat experience) than aviators in the ARNG.

- Similar to ARNG aviators, First Army USAR aviators are generally satisfied with their civilian and USAR jobs and generally intend to stay in the USAR until they are eligible for at least a 20-year retirement. Factors that influence aviators to remain in the USAR include the opportunity to fly, pay, and retirement benefits. Factors that may influence aviators to leave the USAR include administrative details and politics, unrealistic training goals for the time and resources allocated, and loss of flight status.

- First Army USAR aviators generally rate the amount of time available to meet continuation training require-ments as inadequate and are willing to spend addi-tional paid time to meet the requirements. This finding is consistent with the results from the ARNG aviation survey.

- Similar to the ARNG aviators, First Army reserve aviators judged that the unavailability of instructor pilots, an insufficient number of flight hours, the unavailability of training areas, and the unavail-ability of aircraft are the major obstacles to meeting continuation training requirements. The aviators judge that an insufficient amount of personal time is a major obstacle to meeting additional military requirements. In general, the unavailability of resources appears to be a more serious problem for First Army reserve aviators than it is for ARNG aviators.

- First Army reserve aviators judge that they need 10 more Additional Flight Training Periods per year to meet the current training requirements. The aviators indicate that they could afford to spend approximately 8 additional paid hours each month meeting the train-ing requirements. No comparable data are available from the ARNG survey.

Work Projected

Completion of the ARIARDA Working Paper completed Anacapa's work on this project, unless First Army requests additional assistance.

References

Ruffner, J. W. (1987). Evaluation of National Guard aviator training requirements. In T. B. Aldrich and D. M. McAnulty (Eds.), Human factors research in aircrew performance and training (Annual Summary Report ASI690-304-87, pp. 54-64). Fort Rucker, AL: Anacapa Sciences, Inc.

Ruffner, J. W., & McAnulty, D. M. (1987). First U.S. Army Reserve aviator questionnaire data summary. (Working Paper FR/ARDA/ASI-88-1). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences.

Ruffner, J. W., & Szabo, S. M. (1986). An evaluation of Army National Guard aviator training time utilization (Technical Report ASI678-201-86[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

Szabo, S. M., Ruffner, J. R., Cross, K. D., & Sanders, M. G. (1986). An evaluation of training requirements of Army National Guard aviators. Phase 1: Analysis of questionnaire data (ARI Research Report 730). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A180 639)

DGFS AVIATION AMMUNITION AND GUNNERY SURVEY

Dr. D. Michael McAnulty, Project Director

Background

In January 1987, the Department of Gunnery and Flight Systems (DGFS) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, requested that the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) provide research support in conducting an ammunition and gunnery survey of active Army (AA) and National Guard (NG) aviation units. ARIARDA agreed to assist in designing and pretesting the survey; to develop the data entry, verification, and analysis programs; to conduct the required data analyses; and to prepare briefing materials and technical reports as required. All other project activities (e.g., administrative coordination, pretesting, data collection, data entry) were to remain the responsibility of the DGFS Study Group.

Problem

The survey research was designed to provide an empirical data base for addressing three major problem areas. First, the increasing cost of ammunition and the competition for Department of Defense funds have created pressure to reduce the annual allocation of ammunition for Army aviation gunnery training. The research was intended to document the current utilization of ammunition in aviation gunnery training, to evaluate the success of the gunnery training, and to compile estimates of the amount of ammunition required to maintain specified Standards in Training Commission (STRAC) readiness conditions. In addition to justifying the ammunition allocations, the resulting data base was used by DGFS to develop a new gunnery training manual.

The second major problem is the lack of adequate ranges on which to train and qualify unit aviators. Many units complain that the available ranges lack the targetry, scoring devices, and space required for effective training. Furthermore, limited access to the ranges inhibits the gunnery training and makes it difficult to maintain the required readiness conditions. The research was intended to document the availability, type, and utility of gunnery ranges currently in use by Army aviation units.

The final major problem is the lack of empirical data about the utility of flight simulators for weapon systems

training. Theoretically, flight simulators can reduce the impact of the first two problems. That is, weapon training can be conducted without ranges and without incurring ammunition costs. However, there are no data that identify the tasks that can be trained effectively in simulators, the amount of training that is most cost-effective, or the extent that flight simulator training can offset the need for weapon firing in the aircraft.

This problem is compounded by the single configuration of the AH-1 attack helicopter flight and weapons simulator (FWS) that is used by unit aviators who fly different configurations of AH-1 attack helicopters (e.g., AH-1G, AH-1S Modified, and AH-1S Production models). The FWS is configured like the AH-1S Fully Modernized helicopter. The survey research was designed to collect information about the utilization of flight simulators for conducting aerial weapons training.

Research Methodology

In January 1987, the Commanding General of the USAAVNC directed that a survey of field unit aviators and aviation unit commanders be conducted to compile the research data required to:

- describe the current attack aviation force,
- formulate an accurate ammunition procurement request,
- evaluate the training value of flight simulators for aerial gunnery, and
- support revisions to the Army's aerial gunnery training programs.

Despite the extensive nature of the project, reporting commitments to Department of the Army Headquarters dictated that the survey be developed and administered, and the data analyzed by December 1987.

Survey Development

Survey development began with a review of the relevant literature, the then current aerial gunnery training manual (Field Manual (FM) 1-140), and a previous STRAC questionnaire (1987). The DGFS Study Group then delineated the Essential Elements of Analysis (EEA) for the survey. Approximately 100 preliminary survey items were drafted in the following ten topics covered by the EEA:

- personal data about the respondent,
- military experience of the respondent,
- flight experience of the respondent,
- present duty assignment of the respondent,
- suitability of current gunnery training publications,
- weapon systems on the aviator's primary aircraft,
- ammunition allocated and fired during the 1987 training year,
- utilization of gunnery range facilities,
- utility of flight simulators for gunnery training and qualification, and
- door gunnery training.

The preliminary survey items were administered to approximately 50 attack helicopter aviators by DGFS personnel. The results of this pretest were used to produce a second draft of the survey. The second draft was divided into two forms: Form A for the unit aviators and Form B for the unit commanders. Many of the items on the two forms are similar in content, but the unit aviators were instructed to respond to the items with respect to themselves and the unit commanders were instructed to respond to the items with respect to the entire unit, except for their personal data and experience.

A pretest of the second draft of the survey was scheduled but had to be cancelled because of administrative problems at the participating installations. DGFS personnel, acting as aviator subject matter experts, and Anacapa Sciences personnel reviewed and edited the final versions of the survey forms and prepared the required ancillary materials (e.g., letters of instruction). Subsequently, the surveys were approved for use by the U.S. Army Soldier Support Center and reproduced for administration by DGFS.

Form A contains 68 items divided into 9 of the 10 topic areas listed above; no questions are posed to the unit aviators about door gunnery. Form B contains 78 items divided into all 10 topic areas. The surveys are much more comprehensive than the number of items indicates. That is, many items have multiple sections or require a succession of responses. Although all the items did not apply to all the respondents, there are 472 codable responses on Form A and 644 codable responses on Form B. In addition, both forms have several open-ended response items.

Survey Data Collection

During August 1987, DGFS personnel distributed 362 commander forms and 1996 aviator forms to the AA and NG units. The majority of the surveys were administered by installation points of contact. The remainder of the surveys were administered by DGFS personnel conducting visits to field units.

ARIARDA personnel developed computer programs to enter and verify the survey data. The survey responses were entered and verified by DGFS and Anacapa personnel as the forms were returned from the aviators and commanders. Data collection was terminated on 19 November 1987. At that time, 127 (35%) unit commander forms and 810 (41%) unit aviator forms had been completed and returned in usable form to DGFS for processing. In addition, 35 commander and 184 aviator forms were returned either unused or incomplete. The percentage of NG respondents was 36.2% for the unit commanders and 31.9% for the aviators.

Several meetings were held with DGFS personnel to enumerate the most important research issues, to identify the subset of survey items that most directly address those issues, and to develop a statistical approach for analyzing the items. Subsequently, computer programs were prepared to analyze the items that address the major problem areas that led to the initiation of this project. The data were analyzed separately for the AA and the NG because of the major differences in unit mission, types of aircraft flown, and training resources and standards.

Results and Conclusions

The return rates of usable surveys were judged to provide a reliable data base for analysis, although there were limitations on the number of subsample analyses that could be conducted. The voluminous results of the survey data analyses are summarized in the seven general conclusions discussed in the following paragraphs.

1. The AA respondents are, on the average, relatively young and inexperienced in their occupational specialty. The NG aviators are older and more experienced than their AA counterparts, and therefore may be able to maintain their skills at acceptable levels with less training resources. The AA commanders have experience levels that are approximately equal to the NG commanders.

2. The average AA aviator flew slightly more than the minimum number of hours required to maintain his flight skills in Fiscal Year 1987 (FY87), but fired less than the authorized number of ammunition rounds. The average NG aviator flew fewer hours and fired less ammunition than his AA counterpart.

3. A substantial number of AA and NG units were unable to meet their training readiness standards with the resources available to them in FY87. The lack of sufficient ammunition was the most frequently cited reason for not meeting the standards, but other resource limitations were also cited.

4. Gunnery ranges were not readily available to many units or did not have adequate scoring methods. Very few of the ranges were designed specifically for aviation gunnery, and most were shared with other branches. These problems were especially critical for the NG units.

5. The AA aviators used flight simulators for gunnery training to a moderate extent (a median of 10 hours) during FY87. Very few NG units had access to simulators, so their simulator usage data were not analyzed. The AA respondents perceived the simulators to have utility for some types of training tasks but not for other types. Specifically, tasks that were highly dependent on the simulator visual system generally received lower ratings. The lack of physical fidelity between the AH-1S models and the FWS was not judged to impair training on most types of tasks. AH-64 aviators rated the training value of the AH-64 Combat Mission Simulator higher than the AH-1 aviators rated the FWS on 7 of 12 types of training.

6. The respondents indicated a desire for standardized gunnery tables to support the development of unit training programs. The data obtained from the survey respondents constitute a source of information for revising the FM 1-140 tables.

7. The estimates of ammunition requirements indicate that the current STRAC authorizations approximate the minimum number of rounds needed to qualify and sustain the average aviator's gunnery skills. The estimates are supported by the FY87 data on the number of rounds fired (less than authorized) and the percentage of units that did not meet their training readiness standards.

When considering these conclusions, it must be remembered that much of the survey information is based on subjective opinions rather than objective data. Although the survey data provide valuable information, further research,

including longitudinal surveys and empirical experiments, is needed to determine the amount, frequency, and type of training required to ensure that U.S. Army and National Guard attack helicopter units are capable of accomplishing their missions.

Project Status

Work Completed

The following significant project activities have been completed:

- developing Forms A and B of the survey;
- collecting, processing, and analyzing survey data from 810 aviators and 127 unit commanders;
- preparing briefing materials for the User's Conference (November, 1987), Department of the Army Headquarters briefings (December, 1987 and February, 1988), and the STRAC conference (June, 1988);
- preparing a technical report entitled "Army aviation ammunition and gunnery survey: Volume 1: Executive summary" (April, 1988); and
- drafting a technical report entitled "Army aviation ammunition and gunnery survey: Volume 2: Final report" (November, 1988).

Work Projected

The only remaining project activity is to complete the review and editing of the final report. The final report will be submitted to ARIARDA in November 1988.

References

Department of the Army. (1986, October). Helicopter gunnery (FM 1-140). Washington, DC: Headquarters, Department of the Army.

McAnulty, D. M., Cross, K. D., & DeRoush, D. J. (1988, November). Army aviation ammunition and gunnery survey: Final report (ASI690-317-88, Vol. II). Fort Rucker, AL: Anacapa Sciences, Inc.

McAnulty, D. M., & DeRoush, D. J. (1988, April). _Army aviation ammunition and gunnery survey: Executive summary_ (ASI690-308-88, Vol. I). Fort Rucker, AL: Anacapa Sciences, Inc.

Standards in Training Commission (STRAC) Program Directorate. (1987, January). _Final report of FY86 STRAC evaluation of DA Cir 350-85-4 standards in weapons training_. Fort Eustis, VA: Army Training Support Center.

UTILIZATION/EFFECTIVENESS OF FLIGHT SIMULATORS
FOR AVIATION UNIT TRAINING
Dr. George L. Kaempf, Project Director

Background

The Army's Synthetic Flight Training System (SFTS) has been audited by the Army Audit Agency (AAA) on two occasions, first in 1981 and again in 1984. The AAA reports (U.S. Army Audit Agency, 1982, 1985) stated that, although flight simulators had reduced training costs and improved training at the U.S. Army Aviation Center (USAAVNC), the Army had not determined the effects that the employment of flight simulators may have on training in operational aviation units. Specifically, both reports admonished the Army for the manner in which operational tests had been conducted on the SFTS and concluded that the Army had not adequately quantified the return on its investment in flight simulators procured for aviation unit training. The potential returns include reductions in the number of aircraft flight hours required for training and increases in aviators' proficiency and combat readiness (see Kaempf, 1986, 1987).

In both audit reports, the AAA strongly urged the Army to undertake research needed to quantify the return on the investment in flight simulators being procured for operational aviation units. In response to the AAA recommendations, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) and Anacapa Sciences researchers have accomplished simulator effectiveness research under two separate but related taskings. The first tasking was received from the USAAVNC Directorate of Training and Doctrine (DOTD) in June, 1984. The second tasking was received from the Department of the Army (DA) in June, 1986.

DOTD Tasking

The DOTD formally tasked ARIARDA to address the issues raised about the Army's SFTS training program. Specifically, DOTD requested that ARIARDA conduct research to answer such questions as:

• What tasks can best be trained in flight simulators?

• What rate of practice in flight simulators best enables aviators to maintain proficiency?

- How can flight simulators be used to sustain proficiency on skills that are not routinely practiced in the aircraft?

- What effect does simulated gunnery training as a substitute for live-fire training have on aviator proficiency and unit readiness?

DA Tasking

In 1986, the Office of the Deputy Chief of Staff for Operations at DA reviewed the issues concerning the development of flight simulation train' g programs and the fielding of the flight simulators. DA determined that training effectiveness analyses should be conducted for each of the Army's flight simulation systems. The analyses would serve as the basis for the .evelopment of effective training strategies and programs. Subsequently, DA tasked the Training and Doctrine Command to develop and implement, with the assistance of ARIARDA, post-fielding training effectiveness analyses (PFTEA) of the Army's visual flight simulator systems. ARIARDA agreed to develop and implement a plan to address the utilization of flight simulators in operational environments.

Problem

The Army is making a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. High-fidelity simulators are viewed as cost-effective alternatives to flight training in the aircraft. Visual flight simulator systems have been developed for the AH-1F, AH-64A, CH-47D, and UH-60 helicopters. All of these systems are in advanced stages of deployment to operational aviation units.

The Army's objective is to provide training devices in which operational aviators may sustain their flight and tactical skills. However, very little empirical data currently exist (a) to demonstrate that flight simulators effectively and efficiently provide this type of training, and (b) to guide the Army in developing training programs that include an optimum mix of training conducted in the aircraft and flight simulator. These data are needed to ensure that the Army receives the maximum return on its investment in flight simulation.

Research Objectives

The overall objective of this research area is to evaluate the effectiveness of the U.S. Army flight simulator systems for training operational aviators. The objectives of the research projects resulting from the DOTD and the DA taskings are to:

- develop procedures for evaluating flight simulator training effectiveness,
- identify tasks that can be sustained effectively and efficiently in the AH-1 Flight and Weapons Simulator (FWS),
- determine the effectiveness of the AH1FWS and the AH-64 Combat Mission Simulator (CMS) for training crew gunnery tasks and sustaining crew gunnery proficiency in operational aviation units,
- provide the data needed to develop training programs that incorporate a sound mix of flight simulator and aircraft flight training in operational aviation units, and
- identify training techniques and strategies that will enable aviators to maintain their flight and tactical skills in flight simulators.

Research Approach

A series of research projects are required to meet the objectives of this research area. During the current contract year, work was accomplished on five projects. Two of the projects are being conducted in response to the DOTD tasking and three of the projects are being conducted in response to the DA tasking. The initial approach and the specific projects being conducted in response to the DOTD and DA taskings are described below.

Response to the DOTD Tasking

In response to the DOTD tasking, Anacapa and ARIARDA researchers developed a research plan (Cross & Gainer, 1987) designed to answer the issues raised by the first AAA audit and by other simulation experts. The research plan calls for a series of research efforts at the USAAVNC and in operational aviation units. The following two projects were initiated to implement the Cross and Gainer research plan.

Backward transfer and skill acquisition in the AH1FWS. Two experiments were conducted in the first project. In the first experiment, AH-1 instructor pilots at the USAAVNC who

were proficient in the AH-1 but unfamiliar with the FWS, were evaluated on their performance of eight emergency touchdown maneuvers (ETMs). Their performance in the aircraft was compared to their performance in the simulator. The purpose of this experiment was to determine if the AH-1 aircraft and the FWS are interchangeable training devices and to test the utility of the backward transfer paradigm. In the second experiment, four different groups of aviators from operational units each received simulator training on a different set of five maneuvers. The subjects received a maximum of ten practice trials on each maneuver. The purpose of this experiment was to estimate how many practice trials were required to reach a satisfactory level of proficiency on each maneuver.

Transfer of training in the AH1FWS for ETMs. The second project was designed to evaluate the effectiveness of the AH1FWS for training five ETMs that operational aviators normally are prohibited from practicing in the aircraft. An exception to the prohibition was granted by the Army for the purpose of this experiment. Operational unit aviators were given checkrides on the five ETMs in the AH-1 aircraft and in the FWS, and then assigned to a control group or an experimental group. The control group subjects were trained to proficiency on the ETMs in the aircraft. The experimental group subjects were trained to proficiency on the ETMs in the AH1FWS and then trained to proficiency in the aircraft. The effectiveness of the simulator training was tested by comparing the two groups on their aircraft training performance.

Response to the DA Tasking

In support of the DA tasking, Anacapa and ARIARDA researchers developed a PFTEA plan (ARIARDA, 1987) that can be implemented for each of the four simulator systems being procured for the operational aviation units. The PFTEA plan proposes to investigate the effectiveness of each simulator system to acquire and sustain aviator flight skills on groups of selected flight tasks. Several groups of flight tasks will be investigated for each different simulator system; each task group investigated will require a separate sample of subjects. The task groups include:

- emergency touchdown maneuvers,
- basic flight tasks,
- flight with night vision systems, and
- tactical and weapons tasks.

Three projects have been initiated in response to the DA tasking. Each project is briefly described in the following paragraphs.

Training effectiveness analysis of the AH1FWS for conducting gunnery training. This project is designed to evaluate the effectiveness of the AH1FWS for sustaining gunnery skills in operational units. In this experiment, rated and combat qualified AH-1 aviators in U.S. Army, Europe (USAREUR) units will be assigned to one of three groups: one control and two experimental. Each subject's initial proficiency on crew gunnery tasks will be evaluated during a pretest checkride at the live-fire gunnery range.

Following the pretest checkride, Experimental Group 1 aviators will receive gunnery training in the flight simulator every month and Experimental Group 2 aviators will receive gunnery training in the flight simulator every quarter. Aviators in both experimental groups will continue to participate in their units' normal flying programs except for restrictions on the gunnery tasks that they can perform in the aircraft. Aviators in the control group will participate in their units' normal flying programs but will receive no gunnery training in the flight simulator during the research period. Following the 12-month period, all subjects will be evaluated in a live-fire crew gunnery training exercise. The effectiveness of the AH1FWS for sustaining gunnery skills will be tested by comparing the performance of the groups during the live-fire exercise.

Training effectiveness analysis of the AH64CMS for conducting crew gunnery initial qualification training. This second project is designed to evaluate the effectiveness of the AH64CMS for the initial training of aerial gunnery skills up to the crew qualification level. In this experiment, AH-64A aviators from the Apache Training Brigade (ATB) at Fort Hood, Texas, will be assigned to two subject groups: one experimental and one control. During the 8-week research period, the experimental group subjects will receive four periods in the AH64CMS training on specific crew gunnery tasks. The control group subjects will receive no training in the AH64CMS on gunnery tasks. Concurrently, both groups will participate in the unit's normal flying program. Following the training, all subjects will be evaluated in a live-fire crew gunnery training exercise. The effectiveness of the AH64CMS for initial gunnery training will be tested by comparing the performance of the groups during the live-fire exercise.

Training effectiveness analysis of the AH64CMS for conducting crew gunnery proficiency sustainment training. This third project will also be conducted at Fort Hood, Texas, and is designed to evaluate the effectiveness of the AH64CMS for sustaining gunnery skills in operational units. The experimental design is the same as for the project that is designed to evaluate the effectiveness of the AH1FWS for sustaining gunnery skills in operational units.

Project Status

Backward transfer and skill acquisition in the AH1FWS. All data collection and analyses were completed and described for this project during the previous contract year (Kaempf, 1987). During the current contract year, a technical report was drafted to present the findings of the research project. In summary, the results indicate that AH1FWS design deficiencies adversely affect pilot training and performance on selected maneuvers. Specifically, aircraft-proficient aviators required several training trials before they could perform the selected maneuvers satisfactorily in the simulator. The aviators showed significant improvement on all but four of the maneuvers across ten training trials. The results of the two experiments support the utility of the backward transfer paradigm as a relatively inexpensive means of estimating forward transfer of training.

Transfer of training in the AH1FWS for ETMs. All data collection was completed and described for this project during the previous contract year (Kaempf, 1987). During the current contract year, the data were analyzed and a technical report was drafted to report the results of the research project. In summary, the results indicate that the aviators possessed deficient skills on the ETMs prior to the experiment. Furthermore, the aviators required extensive training to reach proficiency in the FWS but relatively little training to regain proficiency in the AH-1 aircraft. Prior training in the FWS did reduce the number of practice trials and the amount of flight time required to reach proficiency in the AH-1 aircraft.

Training effectiveness analysis of the AH1FWS for conducting gunnery training. This project was initiated during the previous contract year. Work during the current contract year consisted of three activities: (a) obtaining approval to conduct the research, (b) coordinating support for the research from various Army agencies, and (c) developing procedures that will be employed during the research.

As reported previously (Kaempf, 1987), ARIARDA submitted a proposed research plan to USAREUR for review and approval. The 7th Army Training Command (ATC) assumed the role of proponent in USAREUR for this action. In October 1987, the 7th ATC reported that neither V Corps nor VII Corps concurred with the plan because the research would adversely affect the units' combat readiness. In November 1987, a revised research plan was submitted to the 7th ATC that:

- restricted subjects to a designated crew station for the research period,
- reduced the number of experimental groups from three to two, and
- increased the number of subjects from 40 to 50.

The 7th ATC obtained concurrence from V and VII Corps for the revised research plan and, on 16 May 1988, issued a message authorizing ARIARDA to begin the planning and coordination required to start the AH-1 PFTEA research. In July 1988, the Anacapa project director relocated to the Federal Republic of Germany and began preparing for the data collection phase.

<u>Training effectiveness analysis of the AH64CMS for conducting crew gunnery initial qualification training</u> and <u>training effectiveness analysis of the AH64CMS for conducting crew gunnery proficiency sustainment training</u>. In March 1988, the Directorate of Gunnery and Flight Systems (DGFS) officials requested that ARIARDA draft a research plan for evaluating the effectiveness of the AH64CMS for training gunnery tasks. DGFS directed that the research (a) identify, on a task-by-task basis, the effectiveness of the CMS for training crew gunnery tasks, (b) focus on the training of flight crews assigned to operational aviation units, and (c) provide data that will support future requests for training ammunition.

The Anacapa project director drafted the research plan and ARIARDA briefed the proposal to DGFS and USAAVNC officials. Because of the concentration of AH-64 resources in the ATB and the 6th Cavalry Brigade - Air Combat (CBAC), ARIARDA identified Fort Hood, Texas, as the optimal site for conducting the research. DGFS and USAAVNC officials approved the research plan. In subsequent briefings at Fort Hood, the ATB concurred with the need for the proposed research but expressed reluctance to commit resources to support the research. The 6th CBAC committed full support for the research project.

During June 1988, final project planning was conducted and data collection was scheduled to begin on 5 July in the

ATB and on 8 August in the 6th CBAC. The 6th CBAC remained
fully supportive of the research project, but the issues of
insufficient range time and insufficient ammunition had not
been resolved. Coordination with the III Corps agencies at
Fort Hood and the Standards in Training Commission Program
Directorate at Fort Eustis, Virginia, resolved both of these
issues. ARIARDA submitted a written research plan for
approval by III Corps and requested that DA task III Corps to
support the ARIARDA research project. DA tasked III Corps to
support the research on 1 July 1988.

Both projects were rescheduled to start in August 1988;
however, additional coordination problems with the support
units at Fort Hood caused the skill acquisition project to be
postponed until December 1988. The live-fire pretest for the
skill sustainment project began on 6 August 1988, but was
suspended on 7 August 1988 because of a malfunction in the
automated area weapons scoring system. The skill sustainment
project was rescheduled for February 1989.

Work Projected

Backward transfer and skill acquisition in the AH1FWS.
During the next contract year, the draft technical report for
this project will be edited prior to submission to ARIARDA
for review. The report (Kaempf, Cross, & Blackwell, 1988)
will be submitted to ARIARDA early in the next contract year.
Unless revisions are required, delivery of the technical
report will complete all activities under this project.

Transfer of training in the AH1FWS for ETMs. During the
next contract year, the draft technical report for this
project will be edited prior to submission to ARIARDA for
review. The report (Kaempf & Blackwell, 1988) will be sub-
mitted to ARIARDA early in the next contract year. Unless
revisions are required, delivery of the technical report will
complete all activities under this project.

Training effectiveness analysis of the AH1FWS for
conducting gunnery training. During the next contract year,
the experimental training and data collection will begin.
The initial live-fire pretest exercise is tentatively
scheduled to begin in late November or early December of
1988. Simulator training will begin in January 1989. If
this project proceeds as scheduled, the final live-fire
exercises will be conducted during January 1990.

Training effectiveness analysis of the AH64CMS for conducting crew gunnery initial qualification training. During the next contract year, the experimental training and data collection will begin for this project. Simulator training is scheduled to begin in December 1988 and end in July 1989. Live-fire crew gunnery training is scheduled to begin in February 1989 and to be completed in June 1989. Subsequently, the data will be processed and analyzed, and a technical report will be drafted to present the project results.

Training effectiveness analysis of the AH64CMS for conducting crew gunnery proficiency sustainment training. During the next contract year, data collection will also begin on this project. Simulator training is scheduled to begin for the experimental groups in March 1989 and to end in February 1990. All subjects will undergo their units' normal flying programs. The live-fire training exercises are scheduled to begin in February 1989 and again in February 1990.

References

Cross, K. D., & Gainer, C. A. (1987). An enumeration of research to determine the optimal design and use of Army flight simulators (Technical Report 763). Alexandria, VA: Army Research Institute for the Behavioral and **Social Sciences. (AD A191 242)**

Kaempf, G. L. (1986, November). Research on the use and benefits of flight simulators for training field unit aviator In K. D. Cross and S. M. Szabo (Eds.), Human factor. research in aircrew performance and training (Final Summary Report ASI479-080-86, pp. 39-60). Fort Rucker, AL: Anacapa Sciences, Inc.

Kaempf, G. L. (1987, November). Utilization/effectiveness of flight simulators for field unit training. In T. B. Aldrich and D. M. McAnulty (Eds.), Human factors research in aircrew performance and training: Annual summary report (Technical Report ASI690-304-87, pp. 89-101). Fort Rucker, AL: Anacapa Sciences, Inc.

Kaempf, G. L. & Blackwell, N. J. (1988). Transfer-of-training study of emergency touchdown maneuvers in the AH-1 flight and weapons simulator (Technical Report ASI690-311-88[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

Kaempf, G. L., Cross, K. D., & Blackwell, N. J. (1988).
    <u>Backward transfer and in-simulator skill acquisition in
    the AH-1 flight and weapons simulator</u>. (Technical
    Report ASI690-312-88[B]). Fort Rucker, AL: Anacapa
    Sciences, Inc.

U.S. Army Audit Agency. (1982). <u>Report of audit: Synthetic
    flight training system</u> (Audit Report SO 82-6).
    Washington, DC: Army Audit Agency.

U.S. Army Audit Agency. (1985). <u>Report of audit: Follow-up
    audit of synthetic flight training system</u> (Audit
    Report SO 85-18). Washington, DC: Army Audit Agency.

U.S. Army Research Institute Aviation Research and Develop-
    ment Activity. (1987, July). <u>ARIARDA resource require-
    ments for PFTEA and AH-1S milestones</u>. Fort Rucker, AL:
    Army Research Institute Aviation Research and
    Development Activity.

DEVELOPMENT AND EVALUATION OF THE
AH-64 DISPLAY TRAINING MODULE

Dr. John W. Ruffner, Project Director

Background

The AH-64 attack helicopter is a two-crewmember aircraft designed to fly nap-of-the-earth missions to detect, engage, and destroy enemy armor during day or night and in all weather conditions. To provide this capability, the AH-64 is equipped with several complex flight and weapons delivery systems. The successful operation of some of these systems requires that the pilot and copilot/gunner (CPG) be able to observe, interpret, and integrate both visual imagery and symbolic information presented on visual displays.

The AH-64 visual display systems that provide information to the pilot and/or the CPG are the Target Acquisition and Detection System (TADS), the Pilot Night Vision System (PNVS), and the Fire Control Symbol Generator. The TADS is used by the CPG for target search, detection, recognition, and designation. Three sensors, the forward-looking infrared (FLIR) system, the day television viewing system, and the direct view optics system, provide the CPG with visual information to detect and engage targets at standoff ranges during day or night and in adverse weather conditions. The PNVS provides FLIR imagery that enables the pilot to fly the aircraft at night and during degraded visibility conditions. The fire control symbol generator superimposes flight and weapons symbology on the imagery displayed by the TADS and PNVS.

Visual imagery and symbology from the TADS and the PNVS can be presented to either crewmember on the panel-mounted cathode ray tube (CRT) displays or through the Helmet-Mounted Display (HMD). The HMD provides a 30° (vertical) by 40° (horizontal) field of view to the crewmember on a 1-inch diameter CRT attached to the helmet. The HMD enables the crewmember to cross-check flight and weapons information while simultaneously viewing the external visual scene.

The 27 different symbols in the PNVS flight symbol set can be presented to assist the crewmember in flying the aircraft. Slightly different subsets of the symbols are presented during hover, transition, cruise, and bob-up modes. The 17 different symbols in the weapons symbol set can be presented to assist the crewmember during the operation of the weapons system. Fourteen symbols are common to both the flight and weapons symbol sets. The symbols vary in size,

shape, location, and the manner in which they represent the status of the aircraft or weapons system elements. Information about an aircraft or weapons system may be represented by changes in symbol size, position, or rate of movement. The number of symbols displayed at any given time depends on the nature of the flight or weapons tasks and the selected symbology mode.

Need

To become fully qualified in the AH-64 attack helicopter, a student aviator must learn to recognize, understand, interpret, and integrate the symbology presented on the helicopter's visual displays. During the AH-64 Aircraft Qualification Course (AQC), student aviators are taught to use the symbology through classroom lectures, videotape presentations, self-study handouts, and technical manuals containing static diagrams of the symbology. Opportunities for additional practice with the display symbology are available on three training devices: (a) the TADS Selected Task Trainer (TSTT), (b) the Cockpit Weapons Emergency Procedures Trainer (CWEPT), and (c) the Combat Mission Simulator (CMS).

The TSTT is a part-task trainer designed to support (a) initial CPG qualification and refresher training in the AH-64, and (b) TADS skill sustainment during mission and continuation training in operational aviation units. It provides practice only with weapons symbology. The CWEPT is a full-scale crew station procedures trainer. It is designed to provide training to the pilot and the CPG in both normal and emergency flight procedures and avionics equipment operation. The CMS is a six degree-of-freedom, motion-based simulator designed to simulate the flight and weapons capabilities of the AH-64 aircraft. It is currently used to provide training in combat mission scenarios during the Combat Skills phase of the AH-64 AQC and during operational aviation unit training.

The training design features of the TSTT, CWEPT, and CMS do not include training on basic symbology identification and interpretation. Students assigned to training lessons on these devices are assumed to be familiar with flight and weapons symbology. However, TSTT, CWEPT, and CMS instructors expend an inordinate amount of time training basic symbology skills in the respective devices. Furthermore, students training in the TSTT, CWEPT, or CMS typically do not have opportunities to use the AH-64 display symbology under the full range of missions, modes, weapons, system options, and

system failures. A device that provides specialized training on basic symbology identification and interpretation would improve the efficiency of TSTT, CWEPT, and CMS instruction.

Project Objectives

The Training and Doctrine Command System Manager for the AH-64 requested that the Army Research Institute Aviation Research and Development Activity (ARIARDA) develop and empirically evaluate a module to train AH-64 student aviators to understand and interpret flight and weapons symbology.

ARIARDA established the following six specific design objectives for the training module:
- be designed in a self-instructional format (i.e., not require an instructor to operate the trainer);
- be designed to provide training in a classroom setting;
- be designed to train symbology for the full range of aircraft mission and weapon system options;
- be capable of storing performance data and providing one or more performance indexes after each training exercise;
- be capable of providing immediate feedback and remedial instruction when errors occur;
- be suitable for both initial skill acquisition in an institutional training setting and skill sustainment training in an operational unit training setting; and
- be flexible enough to allow revisions resulting from (a) design changes in the aircraft, (b) design changes in the avionics system, or (c) deficiencies in the training module revealed by formal evaluation and feedback from the user.

In addition, the training module should be designed to augment but not replace existing training devices. Finally, it should not require the fabrication and use of mockups or other costly training aids.

Research Approach

Ten research tasks are required to accomplish the project objectives. The research tasks are the following:
- review the relevant literature,
- identify the flight and weapons tasks requiring the use of symbology,
- interview subject matter experts (SMEs),

- identify the capabilities and limitations of existing training devices,
- define the scope of training,
- define the training approaches and settings,
- define the terminal learning objectives,
- identify and evaluate the training media,
- design the prototype training module, and
- evaluate the prototype training module.

Project Status

Work Completed

Work began on the project in December 1986. As a result of discussions with SMEs, it was learned that deficiencies in symbology usage exist in the following areas:

- recognizing and interpreting the meaning of symbols presented alone and in the context of other symbols,
- interpreting the meaning of symbology movement,
- correctly associating switch actions and control movements with static or dynamic symbology, and
- selectively attending to and interpreting display symbology when the symbology is superimposed on a dynamic external visual scene.

A decision was made to design the display symbology training module in two parts. Part I will cover basic symbology usage skills and will address the first two deficiency areas cited above. It is organized into five self-contained lessons that present instructional material and quizzes on the following groups of symbols:

- position/movement symbols,
- attitude/altitude symbols,
- heading/navigation symbols,
- cueing/reference symbols, and
- weapon delivery symbols.

Part II will cover advanced symbology usage skills and will address the last two deficiency areas. The specific content and organization of Part II had not been determined by the end of the current contract year.

Work on the training module was suspended at the end of December 1987 because of funding constraints and other project's priorities. The portions of the training module that had been developed by that time are described in the following paragraphs.

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The training module consists of (a) an introductory section, (b) a help system that is accessible from any part of the training module, and (c) tutorials and quizzes for Lesson 1 (Position/Movement Symbols) and Lesson 2 (Attitude/ Altitude Symbols). The tutorials contain static frames and animated sequences, as appropriate.

The help system includes the following features:
- an overview of the entire symbology training module;
- an explanation of the types of help provided (e.g., procedural and content);
- a list of the contents of the five lessons comprising the training module;
- an acronym glossary;
- a symbol dictionary; and
- a symbology mode dictionary.

The symbol dictionary consists of 27 screens, one screen for each symbol. Each screen contains:
- a graphic representation of the symbol;
- the symbol's name;
- the purpose of the symbol;
- the modes in which the symbol appears (e.g., hover, bob-up, cruise, and transition);
- failure actions associated with the symbol; and
- the tutorial lesson(s) in which the symbol is presented.

The symbology mode dictionary consists of four screens showing, for each symbology mode, a complete set of the symbols that can appear in that mode and the purpose of the mode. Symbols that are specific to one of the modes are shown in a different color than the symbols that are specific to the other three modes.

The storyboards for the Lesson 3 (Heading/Navigation Symbols) tutorial and quiz have been developed, but have not been coded on the computer. A draft version of the storyboards for the Lesson 4 (Cueing/Reference Symbols) tutorial and quiz have been completed and reviewed by members of the Anacapa Sciences staff, but have not been revised and coded. No work has started on Lesson 5 (Weapons Usage Symbols) or on Part II of the training module.

The training module is written in compiled BASIC language and is designed to run on a Zenith PC AT-compatible microcomputer equipped with one megabyte of random access memory, a 20-megabyte internal hard disc, an enhanced graphics adapter (EGA), and a high resolution EGA color monitor.

The portions of the display symbology training module that were completed by the end of December 1987 were demonstrated for the ARIARDA Contracting Officer's Technical Representative during the first week of January 1988. No additional work has been performed on the project since that time.

At the end of the current contract year, ARIARDA directed Anacapa to terminate the project. ARIARDA requested that Anacapa submit as project deliverables a brief project summary, storyboards, and computer programs that have been developed.

Work Projected

A brief project summary, storyboards, and computer programs will be submitted to ARIARDA as project deliverables early in the next contract year.

DEVELOPMENT OF THE BASIC MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE (MITAC)

Dr. Dudley J. Terrell, Project Director

Background

In the modern battlefield, Army aviators will be forced to fly at extremely low altitudes to avoid detection by enemy electronic sensors. Because of the need to maintain obstacle clearance while remaining masked by terrain features, low altitude flight requires constant vigilance outside the cockpit. Momentary shifts of attention to displays, switches, and maps inside the cockpit must be executed rapidly and efficiently. Consequently, low altitude navigation requires superior skill in map interpretation and terrain analysis. To remain geographically oriented at all times, a pilot must be capable of gleaning crucial map information during brief glances inside the cockpit and associating that information with the rapidly changing terrain outside the cockpit.

Traditional methods of low altitude navigation training have been unsatisfactory (Fineberg, Meister, & Farrell, 1978; Gainer & Sullivan, 1976; McGrath, 1976). Therefore, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has conducted research to address the low altitude navigation training deficiency. In 1976 Anacapa Sciences, under contract to ARIARDA, developed the Map Interpretation and Terrain Analysis Course (MITAC). The MITAC comprised numerous photographic slides and motion picture films of terrain features and map segments designed to teach low altitude navigation skills to helicopter pilots in a classroom format. Subsequently, the course was revised to an individualized training format utilizing the equipment of the Beseler Cue/See system (Harman, 1978). Holman (1978a, 1978b) demonstrated the effectiveness of this course by showing that MITAC-trained student pilots and enlisted aerial observers navigated at twice the speed and with one-third of the errors committed by traditionally trained aviators.

Thirteen additional cinematic exercises were developed to provide supplemental training in map interpretation and terrain analysis over a wider range of geographic regions and climates (Kelley, 1979). Each of these exercises consists of a film taken from the front window of a helicopter flying a route at low altitude. The exercises include flights over various geographic regions (e.g., Kentucky, Idaho, Arizona, and Germany) with both snow-covered terrain and summer foliage. These supplemental exercises, termed the Advanced MITAC, have been upgraded to a computer-based interactive

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videodisc format (Miles & LaPointe, 1986). Terrell (1988) demonstrated the training effectiveness of the computer-based Advanced MITAC by comparing the contour-level navigation performance of student pilots who had received the supplemental training with those who had not. A significantly greater proportion of Advanced MITAC students than control (no MITAC) students performed perfectly (i.e., no deviations from the prescribed route) during the post-training navigation test.

Need

Conversion of the Advanced MITAC exercises to an interactive videodisc format has resulted in an easy-to-use and effective part-task trainer. However, the material and equipment for the original "Basic" MITAC (e.g., 35-mm slides, booklets, projectors, tape players, etc.) are difficult to use and are unsuitable for computer-based training. A computer-based course that presents basic principles of map interpretation is needed to serve as a prerequisite course to the Advanced MITAC and for use in the ARIARDA research program.

Project Objectives

The goal of this project is to develop a videodisc/computer-based Basic MITAC. Specifically, the objectives are to:

- develop the Basic MITAC videodiscs, and
- design experimental courseware for the Basic MITAC.

Development Approach

Development will proceed in two phases. In Phase 1, the material from former versions of Basic MITAC will be compiled and upgraded for videodisc development. In Phase 2, instructional strategies will be planned and software written to implement the strategies. Training effectiveness evaluations of the Basic MITAC instructional strategies will be conducted under a separate project title (see Training Effectiveness of Aviation Part-Task Trainers, pp. 103-108 of this report).

Project Status

Work Completed

Phase 1, development of the Basic MITAC videodiscs, was completed in three stages: production, post-production, and duplication. A summary report of the Phase 1 activities was delivered to ARIARDA for review (Terrell & Miles, 1988).

Production. The production stage was accomplished by Anacapa researchers. The primary activities accomplished during the production stage were:

- composition of a narrative for the Basic MITAC,
- selection of video material to supplement the narrative, and
- development of a script containing the narrative and instructions for taping the narrative and video material.

The narrative was developed from (a) a set of illustrated lectures for Marine infantrymen (Cross & Rugge, 1982), (b) a classroom handout on low altitude map interpretation for Army aviation students (McGrath, 1975), and (c) the Defense Mapping Agency guidelines for drawing 1:50,000-scale topographic maps. Many of the slides, maps, and charts from the original MITAC (i.e., the Beseler Cue/See version) were selected for the Basic MITAC. Additional slides were made by photographing various geographic features in the Fort Rucker, Alabama, training area. New and updated maps were matched to the features on the slides. Computer-generated graphics and animation were designed to supplement portions of the narrative. Finally, the video material was matched to the appropriate segments in the narrative, and instructions were written about the sequence and timing of audio and video material.

Post-production. The post-production was accomplished under subcontract by Video Technics, Inc., of Atlanta, Georgia. The primary activities accomplished during the post-production stage were:

- recording the narrative on audio tape,
- generating computer graphics and animation,
- digitizing video material,
- editing video material on 3/4-inch videotape, and
- dubbing audio and video on 1-inch master videotape.

After the narrative was recorded, the audio tape was time-coded according to the instructions. Graphics artists generated charts and animation segments using 2-dimensional

and 3-dimensional computer graphics packages. The slide and map images were digitized with a digitizing camera and stored in computer files. Then the digitized images, computer-generated charts, and animation were transferred to 3/4-inch tape according to the instructions and edited against the time-coded audio tape. The audio and video material were combined when the 1-inch master tape was dubbed.

Duplication. Duplication was accomplished by Optical Recording Project/3M in St. Paul, Minnesota. The primary activities during the duplication stage were:
- generating a master videodisc from the 1-inch master tape, and
- producing videodisc copies from the master videodisc.

The generation and the duplication of the master videodiscs were accomplished according to the standard procedures of Optical Recording Project/3M.

Work Projected

In Phase 2, instructional strategies will be developed, and a computer will be programmed to provide interactive training using the videodiscs. The computer programs will facilitate the experimental evaluation of several strategies and tactics of computer-based instruction. For example, experimental courseware will be developed to examine:
- different computer-based branching routines for remediating knowledge or skill deficiencies,
- different methods for presenting drills and tutorials,
- the differential effects of full-motion and still graphics,
- the differential effects of digital and analog imagery, and
- the effects of audio narrative on knowledge or skill acquisition.

Finally, the Basic MITAC materials will be turned over to another project for training effectiveness evaluation (see Training Effectiveness of Aviation Part-Task Trainers, pp. 103-108 of this report).

References

Cross, K. D., & Rugge, S. M. (1982). Map interpretation and terrain analysis course (MITAC) for infantrymen: Illustrated lectures (NPRDC Special Report 82-14). San Diego, CA: Navy Personnel Research and Development Center.

Fineberg, M. L., Meister, D., & Farrell, J. P. (1978). An assessment of the navigation performance of Army aviators under nap-of-the-earth conditions (Research Report 1195). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A060 563)

Gainer, C. A., & Sullivan, D. J. (1976). Aircrew training requirements for nap-of-the-earth flight (Research Report 1190). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A030 420)

Harman, J. (1978). Evaluation of the Beseler Cue/See as a substitute for the L-W analyst projector for MITAC II (Research Problem Review 78-8). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A076 714)

Holman, G. L. (1978a). Effectiveness of a map interpretation and terrain analysis course on NOE navigation training of crewchief/observers (Research Report 1197). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A060 564)

Holman, G. L. (1978b). Evaluation of a map interpretation and terrain analysis course for nap-of-the-earth navigation (Research Report 1198). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A060 565)

Kelley, G. R. (1979). Final letter report on the development of supplementary exercises for Army map interpretation and terrain analysis course (MITAC) (Final Report DAHC19-77-C-0043). Santa Barbara, CA: Anacapa Sciences, Inc.

McGrath, J. J. (1975). Map interpretation in nap-of-the-earth flight (Technical Report No. 215-2). Santa Barbara, CA: Anacapa Sciences, Inc.

McGrath, J. J. (1976). A technical approach to the evaluation of navigation systems for Army helicopters (Final Report 266-1). Santa Barbara, CA: Anacapa Sciences, Inc.

Miles, C. O., & LaPointe, J. L. (1986). Development of a videodisc version of Advanced MITAC training exercises. In K. D. Cross and S. M. Szabo (Eds.), Human factors research in aircrew performance and training (Final Summary Report ASI479-080-86, pp. 95-98). Fort Rucker, AL: Anacapa Sciences, Inc.

Terrell, D. J. (1988). Effects of advanced MITAC training on contour-level navigation performance (Technical Report ASI690-314-88[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

Terrell, D. J., & Miles, C. O. (1988). The basic map interpretation and terrain analysis course (MITAC) videodiscs (Summary Report ASI690-313-88). Fort Rucker, AL: Anacapa Sciences, Inc.

SURVEY OF RESEARCH IN COMPUTER-BASED
INSTRUCTIONAL STRATEGIES
Dr. Dudley J. Terrell, Project Director

Background

Experimental research concerning computer-based instructional strategies is a recent development from two diverse areas: learning psychology and computer technology (for a review, see Eberts & Brock, 1987). Psychology became involved through the application of learning research to the design of early teaching machines (Benjamin, 1988). A growing interest in the application of computer technology to education has resulted in a new field of research and development called instructional design (Gagné, Briggs, & Wager, 1988). Developments in computer-based instruction promise to increase training effectiveness by capitalizing on the efficiency of the individual learning process while reducing human instructor time. Recognizing this promise, the Department of Defense has promoted computer-based training research through the efforts of the Army Research Institute, the Army Project Manager for Training Devices, the Air Force Human Resources Laboratory, the Navy Personnel Research and Development Center, and the Naval Training Equipment Center (Dallman et al., 1983; O'Neil & Evans, 1983).

Need

Much of the current computer-based training research consists of piecemeal attempts to apply recent hardware and software developments (e.g., interactive videodisc, high-speed personal computers, computer graphics) to existing training programs. Lacking a comprehensive plan for systematic experimentation, such research solves immediate training problems, but fails to provide information about the general utility of training technology and the most cost-effective methods for addressing future training needs. An efficient program of computer-based training research will require a comprehensive plan addressing the following issues.

- What is the best method of identifying the critical learning objectives for the proposed training program?

- What are the underlying learning principles that can be applied during the design and development of the proposed training program?

- What are the best media for presenting the proposed training program?

Scientists at the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) are developing a plan to integrate existing computer-based training effectiveness research projects and to forecast the development of future projects. The development of this comprehensive research plan requires a survey of past research on learning principles and their application during the design of computer-based training programs.

Project Objectives

The goal of this project is to generate research questions that can be addressed in ARIARDA computer-based training effectiveness projects. Specifically, the objectives are to:

- survey the research in computer-based instructional strategies, and
- organize the literature in a manner that will facilitate the development of a research plan for computer-based aviation training.

Research Approach[a]

Under this project, researchers at Anacapa Sciences are conducting a comprehensive survey of research on the application of learning principles to computer-based instructional design. The project will be completed in three phases. During Phase 1, a data base will be compiled of published research in computer-based instructional strategies. During Phase 2, the research results will be evaluated for their immediate applicability to computer-based instructional design. During Phase 3, a list of questions requiring further research in computer-based training will be generated.

Project Status

Work Completed

Phase 1 has been completed. The PsychInfo, Defense Technical Information Center, Educational Resources Information Center, and Dissertation Abstracts International data bases were searched using the key words computer-based

instruction, computer-assisted instruction, computer-aided instruction, interactivity, learning, and training. These searches produced over 185 citations.

An in-house data base format was designed using Microsoft File software and a Macintosh computer. Anacapa researchers reviewed each article. For each article, they composed the summary information needed to complete the following entries in the standardized data base:

- official citation,
- type of document,
- problem or background,
- subjects,
- materials or apparatus,
- procedure,
- results,
- conclusions, and
- reviewer's comments or critique.

Work Projected

During Phase 2, the research reports will be reviewed in more detail. The applicability of the research results to computer-based aviation training will be evaluated. Theoretical papers, position papers, and courseware design guidelines will also be evaluated. These reviews will reveal issues in computer-based training that require further research.

During Phase 3, research questions will be formulated to address the issues identified in Phase 2. These questions will be used to guide the development of a research plan for ARIARDA/Anacapa computer-based training research.

References

Benjamin, L. T., Jr. (1988). A history of teaching machines. American Psychologist, 43, 703-712.

Dallman, B., Pohlman, D., Psotka, J., Wisher, R., McLachlan, J., Wulfeck, W., Ahlers, R., & Cronholm, J. (1983). TRIADS: A foundation for military computer-based instruction. Journal of Computer-Based Instruction, 10, 59-61.

Eberts, R. E., & Brock, J. F. (1987). Computer-assisted and computer-managed instruction. In G. Salvendy (Ed.), Handbook of human factors (pp. 976-1011). New York: Wiley & Sons.

Gagné, R. M., Briggs, L. J., & Wager, W. W. (1988). Principles of instructional design (3rd ed.). New York: Holt, Rinehart, and Winston.

O'Neil, H. F., Jr., & Evans, R. A. (1983). CBI research and development centers--US Army Research Institute for the Behavioral and Social Sciences (ARI). Journal of Computer-Based Instruction, 9, 169-170.

TRAINING EFFECTIVENESS OF AVIATION PART-TASK TRAINERS

Dr. Dudley J. Terrell, Project Director

Background

Many aviation tasks, procedures, and skills are trainable with the use of simulators and part-task training devices (Flexman & Stark, 1987). The development of this training technology requires knowledge of the psychological principles underlying the individual learning processes and effective instructional strategies for various kinds of performance. Several operational training problems at the U.S. Army Aviation Center have been identified by previous research, and prototype training devices have been developed to address these problems (Miles, 1987; Miles & LaPointe, 1986a, 1986b; Ruffner, 1987). While these prototype training devices may remediate existing training deficiencies, they will also serve as vehicles for conducting computer-based instructional strategies research at the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA).

Need

The development of prototype devices for training research is an evolutionary process. Preliminary task analyses, subject matter expert advice, and existing research are used to design the first systems. At several stages in the design process, the devices must be subjected to training effectiveness analyses. The results of these analyses are used to improve the design of the training system. Research designed to evaluate the effectiveness of various instructional strategies provide the basis for making recommendations about the optimal use of the training systems.

Project Objectives

The general purpose of this project is to evaluate the effectiveness of prototype training devices and instructional strategies under development at ARIARDA. Specifically, the project is designed to evaluate the training effectiveness of the videodisc versions of the following devices in a manner that elucidates generally effective computer-based instructional strategies:

- the Advanced Map Interpretation and Terrain Analysis Course (MITAC),
- the Modernized Cobra Preflight Inspection Trainer, and
- the Basic MITAC.

Research Approach

Because the Advanced MITAC, the Modernized Cobra Preflight Inspection Trainer, and the Basic MITAC programs are at different stages of development, a general research approach is presented. The status of the research is described separately for each program in the next section.

To evaluate the effectiveness of computer-based instructional strategies with the ARIARDA part-task training devices, the following tasks must be accomplished:

- design training effectiveness experiments,
- conduct experiments,
- feed results of the experiments back into the courseware design, and
- continue training effectiveness experimentation until maximum training benefit is realized.

Project Status

Advanced MITAC

The original format for this training program was a set of 16-mm film exercises in low-altitude geographic orientation (Kelley, 1979). The 16-mm films have been converted to videodisc, and the exercises have been upgraded to an interactive computer-based training format (Miles & LaPointe, 1986b). The current research and development effort focuses on (a) the general effectiveness of the interactive videodisc method for training geographic orientation skills, and (b) the evaluation of computer-based instructional strategies.

Work completed. An experiment was conducted to evaluate the training effectiveness of the Advanced MITAC and to compare the effects of two methods of computer-based error remediation on inflight navigation performance. Forty-one OH-58 student pilots were given an inflight contour-level navigation pretest at the beginning of the Basic Combat Skills (BCS) course. The students were assigned to one of three groups. The control group, with 13 subjects, received only the standard BCS training. The two experimental groups, with 14 subjects per group, received supplemental navigation

training with the Advanced MITAC in addition to the standard BCS training.

The two experimental groups differed only in the manner in which Advanced MITAC errors were remediated. For one group, errors were followed by a computer presentation of the correct answer and a brief explanation of the navigation strategy that would have produced the correct answer (i.e., errors were computer remediated). For the other group, errors were followed by a requirement to rework the navigation problem (i.e., errors were student remediated). A control group of 13 subjects received only the standard BCS training. At the end of the BCS course, all subjects were given an inflight contour-level navigation posttest.

A significantly larger proportion of experimental subjects than control subjects performed perfectly on an inflight contour-level posttest. Of the experimental subjects who did not perform perfectly, those in the student-remediation group tended to stray slightly farther and to spend more time off course than those in the computer-remediation group. Advanced MITAC training had no effect on the number of times that subjects were assisted on the post-test by an instructor pilot, nor did it affect the distributions of final grades for Terrain Flight Navigation, Map Interpretation, or the BCS checkride.

The findings suggest that Advanced MITAC training is effective for teaching contour-level navigation skills to helicopter pilots. The findings also suggest that computer-generated error remediation might be more effective than student-generated error remediation. However, these findings require confirmation through additional research.

A draft technical report (Terrell, 1988a) was submitted to ARIARDA for review. Additionally, a plan for follow-on research (Terrell, 1988b) was submitted to ARIARDA.

Work projected. Pending approval by ARIARDA, research will be conducted to evaluate the effects of film speed, geographic region, and lesson sequence on Advanced MITAC performance. Further research will be designed to analyze the effectiveness of the Advanced MITAC as a skill sustainment trainer and to investigate whether the Advanced MITAC exercises can be used to diagnose geographic orientation skill deficiencies. The Advanced MITAC also will be used as a vehicle for the planned ARIARDA research on computer-based instructional strategies (see Survey of Research in Computer-Based Instructional Strategies, pp. 99-102 of this report).

Modernized Cobra Preflight Inspection Trainer

The original format for this training program was an interactive videotape controlled by a microcomputer (Miles & LaPointe, 1986a). Preliminary research demonstrated the effectiveness of the experimental program as measured by performance on a preflight inspection multiple-choice test (Intano, 1988). However, incidental observations during this research suggested that the videotape format was less suitable than videodisc for computer-based training. The current research effort focuses on development of a videodisc version of the training program and the evaluation of computer-based instructional strategies with the videodisc version of the trainer.

Work completed. The videotape was converted to a videodisc format, and initial courseware design and programming has begun. Software has been developed for dual-screen viewing of the videodisc contents. The native monitor of a host computer is used to display program instructions and computer-generated graphics. A second monitor is used to display video from the videodisc player. The program senses the graphics hardware available on the host computer and adjusts its output accordingly. The dual-screen viewing software does not include any interactive courseware, but does permit easy and organized access to the videodisc information.

A second program was designed and developed for presenting edited information from the videodisc. This program uses a single switching monitor and requires a special video overlay card in the computer. Computer-graphic menus are provided using the organization of preflight inspection checkpoints specified in the TM 55-1520-236-10 and the AH-1 Prod checklist. The student interacts with the computer by operating a "mouse" rather than typing on a keyboard. This version of the training program currently is being field tested in the flightline classrooms of the AH-1 Aviator Qualification Course at Fort Rucker, Alabama.

Work projected. As with the Advanced MITAC, the Preflight Inspection Trainer will be used as a vehicle for conducting the planned ARIARDA research on computer-based instructional strategies. Experimental courseware will be developed, and training effectiveness research will be conducted. Future research and development will utilize the videodisc format in an analysis of computer-based strategies for training crewchief maintenance of the AH-1. Finally, research will be conducted to analyze the effectiveness of the computer-based videodisc training device for skill

sustainment training in operational Army aviation units and in various Army Reserve and National Guard units. The supportability of the computer-based videodisc training device in operational Army aviation units and in various Army Reserve and National Guard units also will be investigated.

Basic MITAC

The Basic MITAC is currently being developed by Anacapa Sciences under a different project title (see Development of the Basic Map Interpretation and Terrain Analysis Course, pp. 93-98 of this report). Upon completion of that project, training effectiveness evaluations will be conducted under the present project.

Work projected. Experiments will be designed and initiated to evaluate the effectiveness of various instructional strategies. Different computer-based branching routines for remediating knowledge or skill deficiencies and different methods for presenting drills and tutorials will be compared. The capabilities of the videodisc medium will be evaluated, including the differential effects of full-motion and still graphics, digital and analog imagery, and the effects of audio narrative on knowledge or skill acquisition. In addition, the research will evaluate the effectiveness of the Basic MITAC in training general map interpretation and terrain analysis skills as a prerequisite for Advanced MITAC training.

References

Flexman, R. E., & Stark, E. A. (1987). Training simulators. In G. Salvendy (Ed.), Handbook of human factors (pp. 1012-1038). New York: Wiley & Sons.

Intano, G. P. (1988). The AH-1S preflight interactive videotape. ARI Research Focus (Fort Rucker Field Unit, No. 5). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences.

Kelley, G. R. (1979). Final letter report on the development of supplementary exercises for Army map interpretation and terrain analysis course (MITAC) (Final Report DAHC19-77-C-0043). Santa Barbara, CA: Anacapa Sciences, Inc.

Miles, C. O. (1987). Development of an upgraded Basic MITAC using an interactive videodisc format. In T. B. Aldrich & D. M. McAnulty (Eds.), Human factors research in aircrew performance and training (Annual Summary Report ASI690-304-87, pp. 102-106). Fort Rucker, AL: Anacapa Sciences, Inc.

Miles, C. O., & LaPointe, J. L. (1986a). Development of an interactive videotape for training AH-1S preflight inspection. In K. D. Cross and S. M. Szabo (Eds.), Human factors research in aircrew performance and training (Final Summary Report ASI479-080-86, pp. 91-94). Fort Rucker, AL: Anacapa Sciences, Inc.

Miles, C. O., & LaPointe, J. L. (1986b). Development of a videodisc version of Advanced MITAC training exercises. In K. D. Cross and S. M. Szabo (Eds.), Human factors research in aircrew performance and training (Final Summary Report ASI479-080-86, pp. 95-98). Fort Rucker, AL: Anacapa Sciences, Inc.

Ruffner, J. W. (1987). Development and evaluation of the AH-64 symbology training program. In T. B. Aldrich & D. M. McAnulty (Eds.), Human factors research in aircrew performance and training (Annual Summary Report ASI690-304-87, pp. 107-111). Fort Rucker, AL: Anacapa Sciences, Inc.

Terrell, D. J. (1988a). Effects of Advanced MITAC training on contour-level navigation performance (Technical Report ASI690-314-88[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

Terrell, D. J. (1988b). Effects of film speed, geographic region, and sequence of regions on Advanced MITAC performance (Research Plan ASI690-310-88[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

TECHNICAL ADVISORY SERVICE: LHX SIMULATION REQUIREMENTS

Mr. Theodore B. Aldrich, Technical Advisor

Background

As part of its aviation modernization program, the U.S. Army plans to develop and acquire a new, highly combat-effective and affordable helicopter to eliminate projected deficiencies in the light helicopter fleet. The proposed new light helicopter, designated the LHX, will have many advanced technology features to increase its effectiveness, maintainability, and survivability.

Anacapa Sciences, under contract to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA), has been providing technical support to the LHX program since July 1983. Anacapa and ARIARDA researchers developed a methodology for predicting crew workload in emerging aircraft. They applied the new methodology to predict operator workload for 42 different conceptual designs of the LHX featuring various automation options in both the one-crewmember and two-crewmember configurations (Aldrich, Szabo, & Craddock, 1986).

Concurrent with the early LHX conceptual design activities, the Army contracted for a multi-year, Advanced Rotorcraft Technology Integration (ARTI) development program. Each of five contractors was required to develop an advanced technology mission equipment package for the light helicopter battlefield mission projected for the year 2000. In addition, each contractor was required to perform a detailed mission/task analysis, develop or adopt a workload prediction methodology, and apply it to the operator tasks imposed by the proposed mission equipment package design.

Because of the expertise gained in developing and exercising the LHX workload prediction model, Anacapa researchers participated in the evaluation of each ARTI contractor's developmental efforts. The Anacapa support included (a) visits to each of the contractor plants to help evaluate the full-mission simulation demonstrations, and (b) participation in all ARTI program reviews to help evaluate the human factors aspects of the proposed designs.

Within the past year, the Army has modified the design goals for the LHX program. The new proposed LHX design is for a two-crewmember aircraft that is single-crewmember operable from one crew station and has a fly-home capability in the other crew station. There are also changes in the

empty design weight goal, the LHX engine, and the design-to-cost goal. The first activities in the revised LHX system development program is an 18-month Demonstration/Validation (DEM/VAL) phase. For the DEM/VAL phase, the Army plans to award equally funded contracts to two contractor teams. Following the DEM/VAL phase, the Army anticipates competitive selection of a contractor team to produce the LHX.

As part of the DEM/VAL program, each contractor team is required to conduct engineering simulations of their (a) cockpit automation and design approaches, (b) mission equipment package/armament system integration, (c) manpower and personnel integration/training initiatives, (d) flight/handling qualities, and (e) mission effectiveness. Because of Anacapa's experience with the earlier LHX and ARTI programs, ARIARDA requested that the Anacapa technical advisor support the revised LHX program in the area of human factors simulation requirements.

Support Provided

During the current contract year, the Anacapa technical advisor attended three meetings concerning the LHX simulation requirements. The first meeting was conducted at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, on 25 May 1988. Prior to the meeting, the Anacapa technical advisor reviewed the draft "Light Helicopter System (LHX) Demonstration/Validation Request for Proposal" and the draft "Light Helicopter System (LHX) Specification." Topics discussed at the first meeting included:

- whether the Army should impose simulation requirements on the LHX contractors similar to those imposed during the ARTI program,
- whether the Army should provide the contractors with (a) a standard mission scenario, (b) Army pilots to serve as subjects, and (c) a standard set of performance measures for the simulation program,
- whether a standard workload prediction methodology should be imposed on the contractors, and
- whether a simulation evaluation team (SET) of Army experts should be formed to evaluate the contractors' simulation studies and results.

The discussion continued at the second meeting, which was held at the Crew Station Research and Development Facility (CSRDF), NASA Ames Laboratory, Moffett Field, California, on 26 and 27 July 1988. During this meeting, the LHX Program Office indicated that a standard mission scenario should be developed and provided to each of the contractor

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teams to make the simulation results comparable. The
attendees decided that the standard scenario also should be
compatible with the capabilities of the CSRDF.

An approach for deriving measures of effectiveness
(MOEs) from the submeasures of performance collected during
simulations was discussed at this second meeting. Although
performance will probably be measured at the task level
(e.g., maintaining altitude), the decision makers are
interested in more global MOEs such as targets destroyed,
threats identified, and the use of battle resources. A
computer-based methodology was demonstrated for collecting
subject matter expert judgments about the importance of each
of the submeasures to the respective MOEs. Attendees
suggested MOEs and submeasures they thought appropriate. The
Anacapa technical advisor suggested the following
submeasures:

- (under MOE, Target Interactions) Engagement Time and
  Maintaining Sight of Target (Air-to-Air),
- (under MOE, Piloting and Navigation) Energy Manage-
  ment, and
- (under MOE Workload) Task Reallocation Among Crews and
  Crew Coordination Errors.

During the discussion, it was learned that the LHX
Program Manager had directed that a SET should not be formed
during the DEM/VAL period of the program. However, an
evaluation team may be formed in conjunction with the LHX
Source Selection Evaluation Board. Therefore, a decision was
made to develop a plan for a SET composed of Army evaluation
pilots and government evaluation engineers and to staff the
plan within the LHX program office and the Directorates of
Combat Developments at the USAAVNC and the Training and
Doctrine Command.

The third meeting, conducted at the USAAVNC, continued
the discussions about performance measures required for LHX
developmental simulation programs. Three action were taken
at the meeting after attack helicopter pilots and other
subject matter experts had critiqued the list of MOEs and
submeasures. First, the MOEs were divided into three cate-
gories: Ground Target measures, Air Target measures, and
Reconnaissance measures. Second, the Piloting and Navigating
MOE was separated into two distinct MOEs, one for Piloting
and another for Navigation. Finally, Degradation in Task
Performance was added to the list of submeasures under the
Workload MOE.

Support Projected

During the next contract year, the Anacapa technical advisor will continue to support LHX developmental simulation efforts as directed by ARIARDA. At the close of the current contract year, the LHX DEM/VAL contracts had not yet been awarded. No additional technical support requirements are anticipated by the technical advisor until the DEM/VAL contracts are awarded.

References

Aldrich, T. B., Szabo, S. M., & Craddock, W. (1986). A computer analysis of LHX automation options and their effect on predicted crew workload (Draft Technical Report ASI479-063-85[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

U.S. Army Aviation Systems Command. (1988). Light helicopter system (LHX) specification (Draft specification). St. Louis, MO: Army Aviation Systems Command.

U.S. Army Aviation Systems Command. (1988). Light helicopter system (LHX) demonstration/validation request for proposal (Draft, DAA J09-88-R-A073). St. Louis, MO: Army Aviation Systems Command.

TECHNICAL ADVISORY SERVICE: SUPPORT TO THE
SPECIAL OPERATIONS AIRCRAFT PROGRAM MANAGER'S OFFICE

Mr. Carl R. Bierbaum, Technical Advisor

Background

The U.S. Army provides aviation support to the Special
Operations Forces, a Department of Defense unit. The CH-47D
and UH-60A aircraft are currently being utilized for aviation
support. However, the Army is developing special aircraft
that will have additional capabilities. The Special Opera-
tions Aircraft (SOA) Program Manager's (PM) Office at the
Army Aviation Systems Command has been tasked to develop the
MH-60K and MH-47E aircraft. These aircraft will consist of
existing CH-47D and UH-60A airframes with a new, integrated
cockpit. A standardized integrated cockpit featuring four
multifunction display (MFD) units will replace the present
CH-47D and UH-60A instrument and gauge configurations.

The MH-60K and MH-47E aircraft are being designed to
provide special operations pilots with aircraft that have
increased capabilities and reduced crewmember workload.
However, the high technology modifications being proposed for
the MH-60K and MH-47E cockpits may increase workload by
placing additional demands on the mental resources of the
crewmembers. Researchers from the U.S. Army Research
Institute Aviation Research and Development Activity
(ARIARDA) and Anacapa Sciences have developed a methodology
for conducting mission/task analyses and predicting workload
for emerging systems (Aldrich, Szabo, & Craddock, 1986).
Additionally, Anacapa researchers, under contract to ARIARDA,
have completed a research product entitled "Task Analysis of
the UH-60 Mission and Decision Rules for Developing a UH-60
Workload Prediction Model" (Bierbaum, Szabo, & Aldrich,
1987). Because of the experience gained from the conduct of
these projects, Anacapa has been tasked with providing
technical advisory services to the MH-60K and MH-47E
development programs.

Support Provided

The primary technical advisory support activities during
the current contract year consisted of participation in:
   • all SOA in-progress reviews (IPRs), and
   • all SOA Crew Station Working Group (CSWG) meetings.
The Anacapa technical advisor participated in the following
IPRs:

- System Design Review   23-24 Feb 88
- CSWG meeting #1   28-31 Mar 88
- CSWG meeting #2   3- 6 May 88
- MH-60K Preliminary Design Review   14-15 Jun 88
- CSWG meeting #3   22 Jun 88
- Hardware Preliminary Design Review   23-24 Jun 88
- Software Specification Review   12-14 Jul 88
- CSWG meeting #4   10-12 Aug 88
- MH-47E Critical Design Review   16-18 Aug 88
- Hardware Critical Design Review/
  Software Preliminary Design Review   13-16 Sep 88
- MH-60K Critical Design Review   27-29 Sep 88

None of the IPRs resulted in a delay in the MH-47E/MH-60K
development programs.

During the System Design Review held at IBM in February
1988, a CSWG was formed to assist the contractors in
resolving SOA design issues. The CSWG met four times on the
following dates: 28-31 March, 3-6 May, 22 June, and 10-12
August 1988. During the first meeting, the basic system
design was described to the members. The briefing included
all MFD control layer and Control Display Unit functions to
ensure that the CSWG members thoroughly understood the
Integrated Avionics System (IAS). The Anacapa technical
advisor attended all four meetings and contributed the
knowledge and expertise gained from the UH-60/CH-47
Task/Workload Analyses project as the CSWG resolved design
issues. The major issues resolved by the CSWG are summarized
below.

- Although the IAS has redundancy throughout the system,
  the CSWG recommended that the following instruments be
  installed as backup instruments:
  --attitude indicator,
  --airspeed indicator,
  --barometric altimeter,
  --radar altimeter,
  --turn and slip indicator,
  --stabilized compass, and
  --accelerometer (MH-60K only).

- When the MFD displays summary pages of data in a
  matrix, the proposed design has a small caret at the
  extreme left of one line to indicate that the line is
  active. The CSWG recommended that, in addition to the
  caret, the selected line be underlined to reduce the
  difficulty in identifying the intersections of columns
  and lines.

- In the SOA design, no information about the fuel available in the auxiliary tanks is provided to the IAS for computation. As a result, the fuel information provided to the pilot by the IAS is inaccurate. The CSWG recommended that sensors be installed in all fuel tanks to provide total fuel available information to the IAS.

- The new capabilities of the MH-60K and MH-47E required that the cyclic and collective grip configurations be redesigned. Additionally, the SOA PM required that the two configurations be standardized as much as the aircraft peculiarities will allow. The CSWG members designed the MH-60K and MH-47E cyclic and collective grip configurations and provided their recommendations to the contractors.

- The forward-looking infrared sensor in the IAS is controlled by a common tracking handle to be used by the pilot or copilot. The CSWG members analyzed optional locations of the tracking handle to ensure easy access by both crewmembers and to reduce any obstruction to the switch panels. Recommendations were provided for both the MH-60K and MH-47E.

- The SOA will have four different modes of navigation available. The SOA PM requested that the CSWG decide which design option should be provided when a higher priority mode is available after a short interruption. The CSWG recommended that the IAS should advise the pilot of the higher priority mode and automatically upgrade after 10 seconds, with the pilot being able to override the automatic mode change during the 10-second delay.

Support Projected

The Anacapa technical advisor will attend the final prototype IPR (the Software Critical Design Review) in December 1988. The technical advisor will attend future meetings of the CSWG when convened by the SOA PM. Anacapa will continue to provide technical advisory support to the SOA PM when tasked by ARIARDA.

References

Aldrich, T. B., Szabo, S. M., & Craddock, W. (1986). A computer analysis of LHX automation options and their effect on predicted crew workload (Draft Technical Report ASI479-063-85[B]). Fort Rucker AL: Anacapa Sciences, Inc.

Bierbaum, C. R., Szabo, S. S., & Aldrich, T. B. (1987). Task analysis of the UH-60 mission and decision rules for developing a UH-60 workload prediction model (Research Report ASI690-302-87, Vols I - IV). Fort Rucker, AL: Anacapa Sciences, Inc.

TECHNICAL ADVISORY SERVICE: SUPPORT TO
AH-64A MODIFICATIONS

Dr. Sandra M. Szabo, Mr. Carl R. Bierbaum, and
Mr. Theodore B. Aldrich, Technical Advisors

Background

In 1987, the Army Aviation Systems Command (AVSCOM) decided to modify the AH-64A aircraft to provide an Airborne Target Handover System (ATHS). The ATHS modification includes the redesign and integration of the AH-64A avionics. One of the primary operational requirements identified for the ATHS Avionics Integration (ATHS/AI) program is a reduction in the amount of time required to perform certain AH-64A mission functions. AVSCOM requested that the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) conduct research to assess the effect that the proposed modifications may have on operator workload. In response to AVSCOM's request, ARIARDA tasked Anacapa Sciences to conduct the required research.

Anacapa had previously conducted a comprehensive task analysis of the AH-64A mission. The analysis provided workload estimates for AH-64A crewmembers and preliminary decision rules for an AH-64A workload prediction model. The model serves as a baseline for evaluating modifications to the AH-64A. The results of that research are reported in Szabo and Bierbaum (1986) and summarized in this report (see Development and Validation of the AH-64A Workload Prediction Model, pp. 23-29).

Anacapa scientists, assisted by AH-64A subject matter experts, supported the ATHS/AI during 1987 by conducting an analysis to:
- identify the crew functions in the AH-64 mission that are most likely to be affected by ATHS/AI,
- identify crewmember tasks that are likely to be eliminated by ATHS/AI,
- identify additional and/or replacement tasks that are likely to be required by ATHS/AI,
- determine the ATHS/AI design goal timelines for the selected functions, and
- compare the ATHS/AI design goal timelines with the baseline timelines for the selected functions.

The AVSCOM program managers adopted the Anacapa design goal timelines and included them in the Army's ATHS/AI request for proposals. The results of the Anacapa ATHS

analysis were reported in Szabo, Bierbaum, and Aldrich (1987).

Support Provided

During the current contract year, Anacapa continued to provide technical assistance to the AH-64A modification programs. In November and December 1987, an Anacapa technical advisor reviewed the timelines and workload predictions and provided information to the AVSCOM Source Selection Evaluation Board for the AH-64A ATHS/AI. The information was used to help evaluate the contractors' methods for evaluating workload associated with their proposed ATHS/AI designs. The Anacapa advisor also assisted in the evaluation of function and scenario timelines submitted by various contractors.

During April and May 1988, Anacapa technical advisors assisted in the evaluation of 74 engineering change proposals (ECPs) for the Rockwell-Collins ATHS. The ECPs were submitted by the U.S. Army Avionics Research and Development Activity (AVRADA) at Fort Monmouth, New Jersey. Anacapa advisors reviewed and evaluated the ECPs and developed recommendations for each of the AVRADA proposals. The evaluations and recommendations were presented at an ATHS users conference at Fort Rucker on 27 April. The Anacapa submission was subsequently adopted and used as a working paper during the user's conference.

During May and June 1988, Anacapa provided technical advice at several meetings concerning the ATHS/AI. The purposes of the meetings were:
- to review additional ECPs developed by Rockwell-Collins International Corporation and to identify the ECPs that should be recommended for the ATHS;
- to discuss an approach for using the AH-64A ATHS to validate a workload prediction methodology, developed by Analytics, Inc., with minimal duplication of effort among Analytics, Rockwell-Collins, and Sikorsky Aircraft Company; and
- to discuss proposed modifications during each phase of an AH-64A Multi-Stage Improvement Program proposed by the McDonnell-Douglas Helicopter Company.

Support Projected

During the next contract year, Anacapa will continue to support modification programs for the AH-64A as directed by ARIARDA.

References

Szabo, S. M., & Bierbaum, C. R. (1986). A comprehensive task analysis of the AH-64 mission with crew workload estimates and preliminary decision rules for developing an AH-64 workload prediction model (Technical Report ASI678-204-86, Vols I, II, III, and IV). Fort Rucker, AL: Anacapa Sciences, Inc.

Szabo, S. M., Bierbaum, C, R., and Aldrich, T. B. (1987). A preliminary analysis of baseline and design goal timelines for AH-64 mission functions affected by ATHS integration (ASI690-307-87[B]). Fort Rucker, AL: Anacapa Sciences, Inc.

TECHNICAL ADVISORY SERVICE: SUPPORT TO MULTITRACK TESTING

Dr. D. Michael McAnulty, Mr. Gary Coker,
Ms. Cassandra Hocutt, Ms. Stephanie Noland, and
Mr. Kenneth Persin, Technical Advisors

Background

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, is conducting research designed to develop a classification algorithm for use in the Initial Entry Rotary Wing (IERW) Course. The purpose of the algorithm is to assign flight students into one of several mission tracks (AH-1, CH-47, OH-58, UH-1, or UH-60) at an early stage of IERW training. During the current contract year, ARIARDA tasked Anacapa Sciences to provide various types of research support for the Multitrack algorithm development.

Research Approach

The ARIARDA research approach involves three phases. First, ARIARDA compiled or adapted existing paper-and-pencil and computer administered tests that may be related to aviator performance into an experimental battery. Second, the tests were administered to high-time aviators in each track and to IERW students to develop an experimental prediction algorithm using a subset of the tests. Third, the experimental algorithm is being validated by administering the tests to entering IERW students, classifying them into mission tracks, and then evaluating their performance in training.

Support Provided

During the current contract year, Anacapa personnel provided the following types of support to the Multitrack Testing project:

- electronic technician support in assembling and maintaining the test apparatus,
- software support in developing the computerized test programs,
- test administration support during the second phase of the research,
- data entry and verification support following test administration, and

- statistical analysis support during the development of the validation algorithm.

Support Projected

Anacapa personnel will continue to provide support to the Multitrack Testing project as required. Because the research is now in the third phase, most of the support will be in equipment maintenance, data processing, and statistical analysis.

TECHNICAL ADVISORY SERVICE: SUPPORT TO HANDEDNESS AND IERW PERFORMANCE

Dr. D. Michael McAnulty, Technical Advisor

Background

In August 1987, Anacapa Sciences was tasked to provide technical support to a research project investigating the relationship between handedness and the performance of helicopter flight students in the Initial Entry Rotary Wing (IERW) Course conducted at Fort Rucker, Alabama. The research project was being conducted under the auspices of the U.S. Air Force School of Aerospace Medicine (SAM), Brooks Air Force Base, Texas. The project was expected to dovetail with the new Flight Aptitude Selection Test (NFAST) project.

Research Approach

The research approach was a straightforward predictive validity study. Students were administered a standardized handedness inventory during the early phases of IERW. Subsequently, performance data were collected and correlated with the results of the handedness scores. The Anacapa technical advisor was asked to provide (a) information about IERW training, (b) advice on experimental design and statistical analysis, (c) biographical information on the tested students, and (d) IERW performance data. The SAM project director made separate arrangements to administer the handedness inventory and to conduct the analyses.

Support Provided

The technical advisor has completed Anacapa's portion of the project unless further support is requested. Usable handedness inventories were completed by 190 students. The technical advisor provided biographical data for 155 students who also participated in the NFAST research. The technical advisor obtained IERW performance data (primary, transition, basic, instrument, and advanced instrument phase flight grades; and the overall average grades at the end of the advanced instrument phase) for 185 of the tested students. No data could be obtained on the other 5 students. Throughout the project, the technical advisor provided assistance on IERW training, experimental design, and statistical analyses as required.

The final activity was to critique a draft project report. The results indicate a significant relationship between handedness and phase flight grades in primary and basic instrument training. In general, right-handers performed better in primary and left-handers performed better in basic instrument training. However, the total variance accounted for by these relationships is very small.

TECHNICAL ADVISORY SERVICE: SOFTWARE DEVELOPMENT FOR
FLIGHTLINE RESEARCH SYSTEMS

Ms. Stephanie M. Noland, Technical Advisor

Background

Scheduling of aviation training resources at the U.S.
Army Aviation Center (USAAVNC), Fort Rucker, Alabama, is a
time-consuming and potentially costly activity. For example,
the 1-14th Battalion currently coordinates and schedules
requests for aircraft, stagefields, refueling, bus and air
transportation, ammunition, and remote landing site lighting.
The scheduling of these resources is accomplished manually; a
mistaken order of only one extra aircraft can cost hundreds
of dollars.

Currently, the resources required for all classes are
scheduled in five-week written projections, one-week updated
written projections, and two daily squaring sessions con-
ducted by telephone. The Army currently uses Form 325 for
this scheduling.

Project Objective

The objective of this project is to develop a computer
hardware and software system that will automate the
scheduling of aviation training resources. An efficient,
automated system will increase speed and accuracy and reduce
the costs of scheduling errors. The U.S. Army Research
Institute Aviation Research and Development Activity
(ARIARDA) contracted with another contractor for development
of the automated system. ARIARDA tasked Anacapa Sciences to
provide software development support to the prime contractor
during the final weeks of the project.

Project Approach

A MicroVax II (VAX) microcomputer was chosen as the
central processor for the scheduling system. Six training
companies and the battalion staff were provided a Zenith 248
personal computer for their use in logging onto the VAX and
for accessing the resident programs and data. The system
design provides customized programs enabling each company to
build, edit, update, and print data about their classes. At
the battalion level, computer programs gather and organize
the information from the six on-line company class files into
battalion reports. The battalion reports include aircraft,
ammunition, stagefield, refueling, bus transportation, and

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air transportation requests for each company. A battalion program gathers the twice daily company change requests into a transaction log to square with the brigade schedules.

The 1-14th Battalion at the USAAVNC was chosen as the prototype training organization for this project because it has the most complex resource requirements. The 1-14th Battalion has six training companies designated with letters A - F. Each company manages between two and five different courses. As many as seven classes may be in residence in a company at any given time.

Support Provided

The work to automate the scheduling process began in February 1988. Anacapa was tasked to assist with the work in July of 1988. Between July and October, the Anacapa technical advisor provided the following support.

Software Problem Diagnosis and Correction

The original automated daily squaring program required two hours to run, whereas the daily squaring could be performed manually in 30 minutes. The Anacapa technical advisor suggested an automated log for recording transactions when the companies make their daily changes. The transactions are sorted by resource affected and automatically recorded in a battalion log. The battalion staff can use this log to square the requests within the required time. The developers have implemented this plan for one training company to date.

Software Development

The Anacapa technical advisor wrote the battalion level software program for consolidating the stagefield and refueling requests from all classes in all companies and for entering the requests onto the appropriate form for each field requested. The forms were designed to match the existing battalion Form 169. The program has been accepted by the 1-14th Battalion.

The Anacapa technical advisor subsequently enhanced the battalion stagefield and refuel request software program to allow for (a) two stagefields or two refueling points to be requested by a class in a single flight period, (b) minimum stagefield requests, and (c) Period 5 or Period 6 requests.

Course Template Development

The Anacapa technical advisor obtained the course flows for each company (B - F) and developed the course templates. A VAX account was established for each company (B - F) with customized programs to operate for their respective courses. The programs were tested using sample classes and demonstrated to Army contacts from each company.

Battalion Program Modification

At the end of the current contract year, the Anacapa technical advisor was assisting the developers in modifying each battalion program to provide the A company request processing capability to Companies B - F.

Support Projected

Work to be completed during the next contract year will include:

- testing the full company and battalion software capabilities,
- bringing all the companies on-line,
- writing user and system documentation,
- training the users from the battalion and each company,
- developing a method of software change control,
- enhancing current software,
- providing system operator support, and
- providing ongoing user support and troubleshooting.